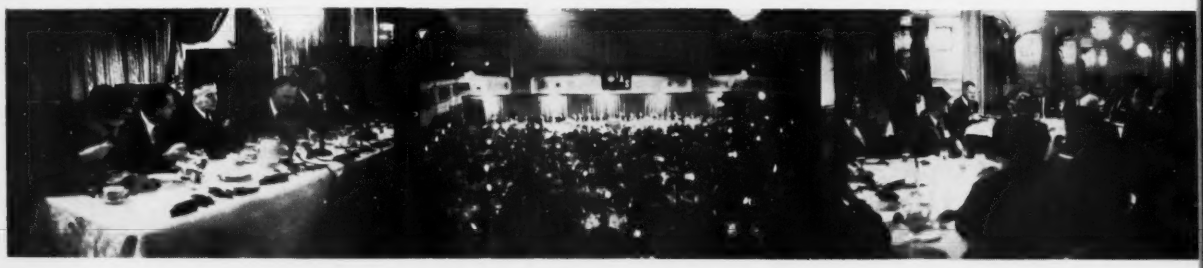
Serial Dept.

AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT · MISSILES · ROCKETS · SATELLITES · SPACECRAFT

IAS

28th Annual Meeting Issue . . .



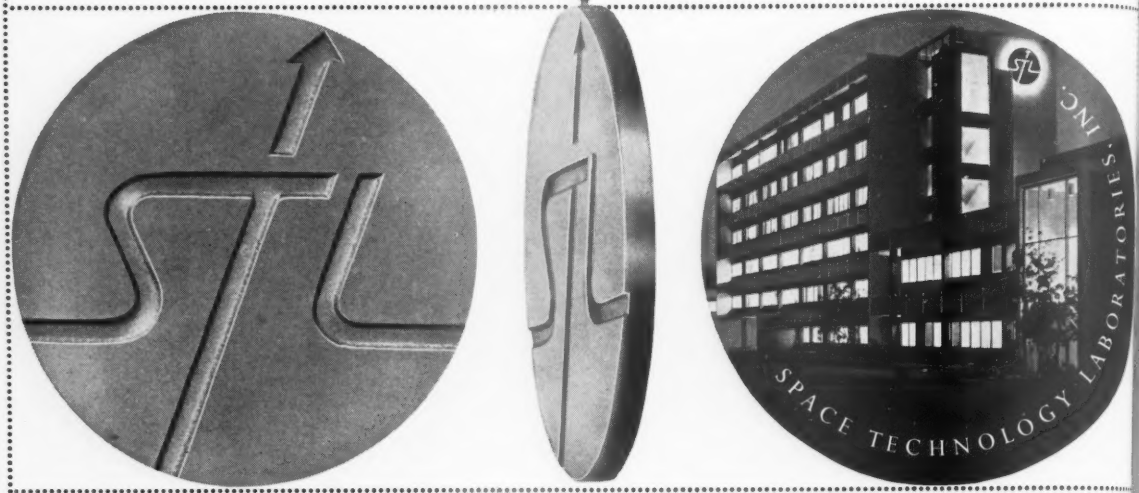
Institute Year: Reports by President, Treasurer, and Director

S Elections, Honors, and Awards

MARCH / 1960

TORIAL: *The Aerospace Technology Panels*

SCIENTISTS AND ENGINEERS: There are two sides to the STL coin...



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AERO/SPACE ENGINEERING

VOLUME 19 / NUMBER 3 **March 1960**

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LETTERS to the Editor

Statistics in Reliability

Re: More on Reliability, AERO/SPACE ENGINEERING, January, 1960

■Mr. Rodert's condescending reply to my comments in the August issue really misses the point. I am well aware not only of the references to which attention is drawn in this reply, but also of many more recent papers in this field, particularly in the *Proceedings* of the IRE Symposium on Reliability. Reference to my recent papers on aircraft safety (AGARD Report No. 153, 1958, and WADC TR 57-131, 1957) may also convince Mr. Rodert that I am quite aware of the differences in the design approach in aeronautical and civil engineering, as well as of the usefulness of probability considerations and statistics.

What I have tried to stress in my remarks in the August issue is the fact that it is the *wrong kind* of statistics that are being applied, and that conclusions based on physically irrelevant statistical assumptions provide misleading answers to the problems of reliability in terms of operational lives. Mr. Rodert's answer really convinces me of the lack of awareness among engineers, aeronautical as well as civil, of the basic problems in the correlation between physical and statistical concepts with respect to their joint application to reliability analysis.

Alfred M. Freudenthal, MIAS
Guggenheim Inst. of Flight Structures
Columbia University

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Comments on Article by Dommasch and Barron

■ The attention of this reader has been attracted by the recent publication of the paper "Optimum Rocket Trajectories, Parts I and II" by Dommasch and Barron.[1, 2] In the opinion of this reader, there is a fundamental error in the paper in question. A detailed discussion follows.

(1) *Direct Analysis*

When an aircraft flies in a vertical plane, four equations must be satisfied at all points of the flight path: (a) equation of forces on the tangent to the flight path, (b) equation of forces on the normal to the flight path, (c) kinematic relationship in the horizontal direction, and (d) kinematic relationship in the vertical direction.

It appears that Dommasch and Barron have treated the problem of maximum altitude rise by considering the dynamical constraints and disregarding partially or totally the kinematical constraints in the formulation of the optimum conditions. Specifically, constraint (d) has been omitted in Part I, while constraints (c) and (d) have been omitted in Part II. Consequently, even though the kinematic and dynamic relationships have been simultaneously considered in the numerical integration of flight trajectories, the majority of the formulas contained in the paper and the numerical analyses summarized in Figs. 1 through 3 of Part II are erroneous in the sense that they do not represent optimum trajectories.

As an example, consider the problem formulated in Part II—that is, the maximum altitude rise in a resisting medium over a spherical earth.[2] Missing in the authors' treatment are the Euler equations associated with the geometric altitude h and the nondimensional range θ. Missing, also, are the Lagrange multipliers associated with the following differential equations*

$$\dot{\theta} - (V \cos \gamma)/(r_0 + h) = 0$$
$$\dot{h} - V \sin \gamma = 0$$

where V is the velocity of the aircraft relative to the earth, r_0 the radius of the earth, and γ the inclination of the flight path with respect to the local horizon. As a consequence, the order of the differential system describing the optimum path is erroneously reduced.

(2) *Pilot Example*

Owing to the complexities of the problems of Lagrange, Mayer, and Bolza, there is a better than even chance that the errors committed by Dommasch and Barron in references 1 and 2 will be clear only to those who have intensively studied the methods of the Calculus of Variations. These errors, however, can be made clear even to the uninitiated if a particular limiting case of the problem considered in Part II is analyzed.

More specifically, consider the problem of extremizing

$$I = \int_1^2 V \sin \gamma dt \qquad (1)$$

under the following assumptions:

(a) The earth is flat, and the acceleration of gravity is constant everywhere.

(b) Newton's law is approximately true for a reference frame rigidly associated with the earth.

(c) The induced drag is negligible with respect to the zero-lift drag.

(d) The mass flow of the rocket engine is constant.

(e) The thrust is tangent to the flight path.

(f) No condition is imposed on the horizontal distance flown by the aircraft.

This problem is a noncontroversial one, insofar as its solution has already been obtained by several authors using different analytical techniques.† As an example, Cicala and Miele[3] have solved this problem by means of the Mayer formulation. Furthermore, Miele has attacked the same problem by means of Green's theorem[4] and the formulation of Bolza.[5] In addition, with reference to the particular case in which the variation in the mass of the aircraft is neglected, solutions have been supplied by Lush[6] using the energy-height method, by Miele[7] using Green's theorem, by Cicala and Miele[8] using the Lagrange formulation, and by Cartaino and Dreyfus[9] using the method of the dynamic programing as developed by Bellman.[10]

In the following sections, the above problem is treated in two ways—first, with the variational approach which has been pioneered by, among others, Behrbohm, Breakwell, Bryson, Cicala, De Veubeke, Leitmann, and Miele (Approach A); then, with the variational approach used by Dommasch and Barron (Approach B).

(2.1) *Approach A*

Owing to hypothesis (c), the drag function has the form $D = D(h, V)$, where h is the altitude and V the velocity. Furthermore, owing to hypothesis (d), the mass of the aircraft is a linear function of time $m = m(t)$ and the thrust of the engine has the form $T = T(h)$. Define now the following function

$$E = (T - D)/mg \qquad (2)$$

and observe that, for the particular problem under consideration, $E = E(h, V, t)$. As a consequence, the equation of motion on the tangent to the flight path is written as‡

$$J_1 \equiv (\dot{V}/g) + \sin \gamma - E(h, V, t) = 0 \qquad (3)$$

where

$$J_2 \equiv \dot{h} - V \sin \gamma = 0 \qquad (4)$$

The Lagrange problem is now formulated as follows: "Among all sets of functions $V(t)$, $\gamma(t)$, and $h(t)$ which are consistent with Eqs. (3) and (4), find that particular set such that the integral (1) is extremized." (*Continued on page 7*)

* The symbols V and $r_0 + h$ of the present Letter to the Editor replace the symbols V_r and h_a of reference 2.

† In reference 5 it is shown that, as long as no condition is imposed on the horizontal distance flown by the aircraft, the problem of maximum altitude rise and the problem of minimum time lead to the same family of extremal solutions.

‡ Notice that the equations of motion on the normal to the flight path and the kinematic relationship in the X-direction are not written. In fact, owing to hypotheses (c) and (f), these two equations do not interact with Eqs. (3) and (4).

The formulation represented by Eqs. (3) and (4) is valid even in the case where hypothesis (c) is omitted, provided the drag is written as $D = D(h, V, L)$ and the equation of motion on the normal to the flight path is formulated as $L - mg = 0$, where L is the lift.

Since the unknown functions are three in number, the optimum path must be consistent with the following Euler equations

$$(d/dt)\ (\partial F/\partial \dot{V}) - (\partial F/\partial V) = 0 \quad (5)$$

$$(d/dt)\ (\partial F/\partial \dot{\gamma}) - (\partial F/\partial \gamma) = 0 \quad (6)$$

$$(d/dt)\ (\partial F/\partial \dot{h}) - (\partial F/\partial h) = 0 \quad (7)$$

where

$$F = V \sin \gamma + \lambda_1[(\dot{V}/g) + \sin \gamma - E] + \lambda_2(\dot{h} - V \sin \gamma) \quad (8)$$

If Eqs. (5) through (8) are combined and if the Lagrange multipliers λ_1 and λ_2 are eliminated, the following result is obtained: the solution arc is composed of subarcs along which

$$\cos \gamma = 0 \quad (9)$$

and subarcs along which

$$\partial(EV)/\partial V - (V/g)\ \partial(EV)/\partial h = 0 \quad (10)$$

This is the result obtained in references (3) through (9).

(2.2) Approach B

With the Dommasch-Barron approach, one has to extremize the integral (1) subject *only* to the constraint (3). This introduces one additional degree of freedom in the problem, but Dommasch and Barron take care of the situation by avoiding the Euler equation relative to the optimization of the altitude. Thus the optimum path is represented by

$$(d/dt)\ (\partial G/\partial \dot{V}) - (\partial G/\partial V) = 0 \quad (11)$$

$$(d/dt)\ (\partial G/\partial \dot{\gamma}) - (\partial G/\partial \gamma) = 0 \quad (12)$$

where

$$G = V \sin \gamma + \lambda_1[(\dot{V}/g) + \sin \gamma - E] \quad (13)$$

If Eqs. (11) through (13) are combined and if the Lagrange multiplier λ_1 is eliminated, the following result is obtained: the solution arc is composed of subarcs along which

$$\cos \gamma = 0 \quad (14)$$

and subarcs along which

$$\partial(EV)/\partial V = 0 \quad (15)$$

The above result points out the incorrectness of the Dommasch-Barron approach. In fact, their approach leads to the well-known optimizing condition for problems of quasi-steady flight,[7] despite the fact that the acceleration terms have been included in the analysis of reference 2. The effect of these acceleration terms, when treating the problem correctly, is to modify the left-hand side of Eq. (15) by the additional term which is present in the left-hand side of Eq. (10).

Conclusions

The detailed analysis of Section 1 and the particular example developed in Section 2 conclusively show that the approach followed by Dommasch and Barron in references 1 and 2 is incorrect.

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[1] Dommasch, D. O., and Barron, R. L., *Optimum Rocket Trajectories: Part I, Initial Value Variational Solutions*, Aero/Space Engineering, Vol. 19, No. 1, Jan., 1960.

[2] Dommasch, D. O., and Barron, R. L., *Optimum Rocket Trajectories: Part II, Generalized Boost Analysis*, Aero/Space Engineering, Vol. 19, No. 2, Feb., 1960.

[3] Cicala, P., and Miele, A., *Brachistocronic Maneuvers of a Variable Mass Aircraft in a Vertical Plane*, Journal of the Aeronautical Sciences, Vol. 22, No. 8, Aug., 1955.

[4] Miele, A., *Optimum Climbing Technique for a Rocket-Powered Aircraft*, Jet Propulsion, Vol. 25, No. 8, 1955.

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[9] Cartaino, T. F., and Dreyfus, S. E., *Application of Dynamic Programming to the Airplane Minimum Time-to-Climb Problem*, The RAND Corp., Report P-834, 1957.

[10] Bellman, R., *Dynamic Programming of Continuous Processes*, The RAND Corp., Report R-271, 1954.

[11] Kelly, H. J., *An Investigation of Optimal Zoom Climb Techniques*, Journal of the Aero/Space Sciences, Vol. 26, No. 12, Dec., 1959.

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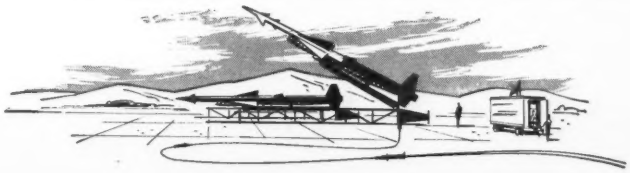
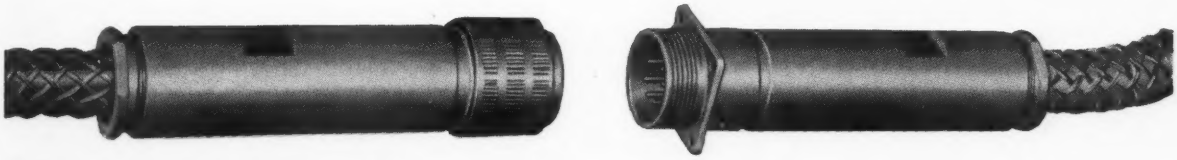
(For Author's Reply, see page 36)





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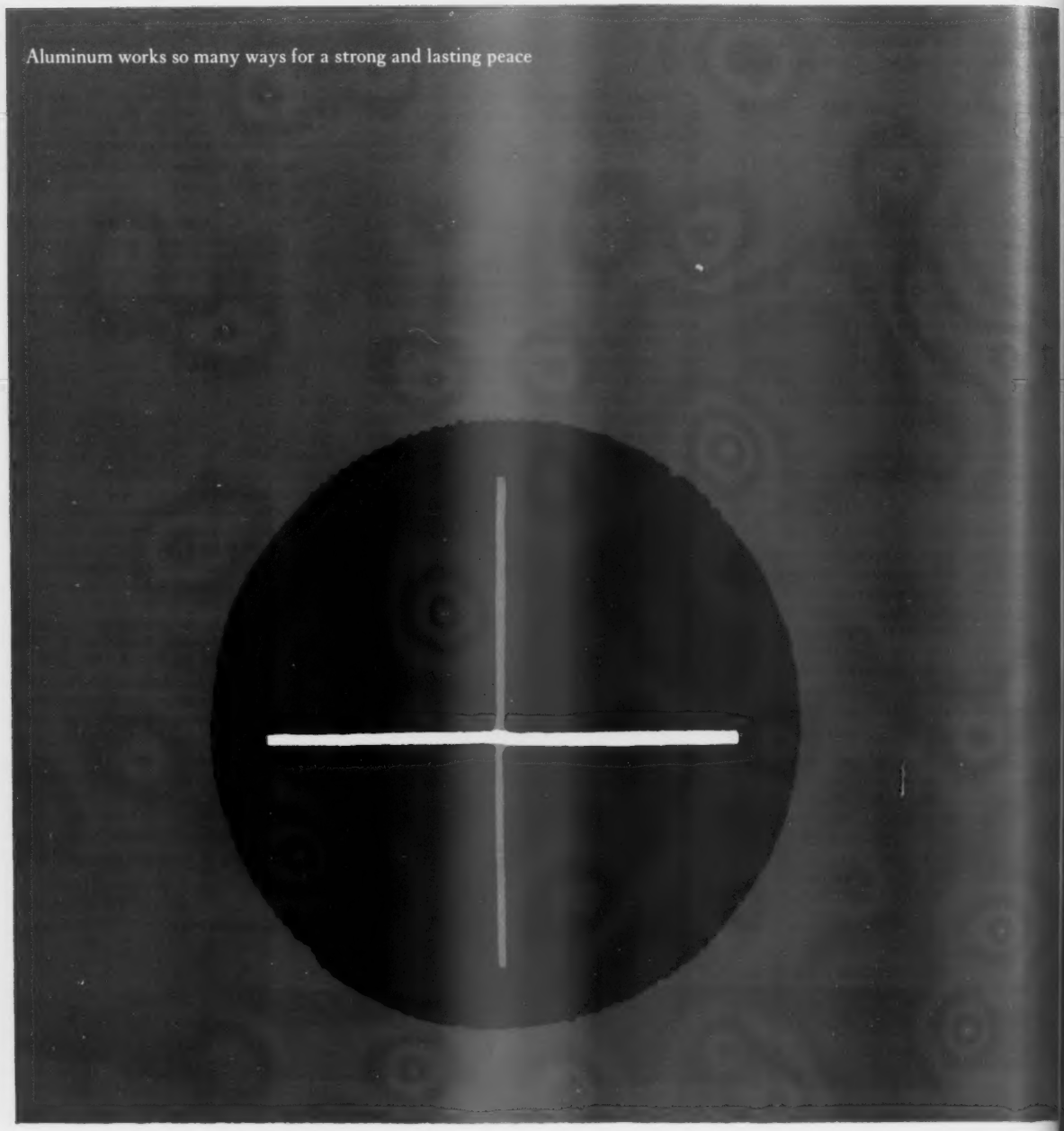

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the Green Sheet

IAS BULLETINS AND LATE NEWS...

March 1960

THE INSTITUTE IN WASHINGTON: In response to an invitation by Chairman Overton Brooks, of the House of Representatives Committee on Science and Astronautics, the IAS participated on Feb. 23 with other key professional societies in a hearing which reviewed problems associated with the national space program. Following a meeting early in the month of several members of the Council with President Donald L. Putt, it was agreed to prepare a House Committee-suggested statement containing official views of the Institute on matters related to the hearing. H. Guyford Stever, Associate Dean of Engineering at MIT, and IAS Council Member, was spokesman for the Institute and appeared with IAS Director Paul Johnston and Secretary Robert R. Dexter. The statement, mailed on the 16th to the Council's Executive Committee with a request for comments, will appear as the editorial in next month's Aero/Space Engineering.

THE FIFTH MINTA MARTIN LECTURE will be presented by Brig. General Benjamin S. Kelsey, USAF (Ret.) at MIT's Kresge Auditorium at 8:00 p.m., March 10. The Lecture is delivered annually in conjunction with a professorship established at MIT in 1954 in honor of Jerome C. Hunsaker, for many years Head of MIT's Aeronautical Engineering Dept., and a Founder Member of the IAS. The late Glenn L. Martin contributed funds providing for presentation of the lecture, named after his mother. General Kelsey, 1959-60 Jerome Clarke Hunsaker Prof. of Aeronautical Engineering, will discuss "Size Considerations in Optimum Aircraft". The lecture will be repeated on March 15 in the Student Union, Univ. of Maryland, and on March 31 at the IAS Building in Los Angeles, Calif.

IAS PRESIDENT DONALD L. PUTT has been appointed a United States national delegate to the NATO Advisory Group for Aeronautical Research and Development (AGARD). The other U.S. delegates are Dr. Theodore von Karman, Chairman of the Group, and Dr. Hugh L. Dryden, Deputy Administrator of NASA, both Honorary Fellows of the Institute.

DR. HERBERT F. YORK, Director, Defense Research and Engineering for the Dept. of Defense, will be guest dinner speaker at the classified meeting on the Future of Manned Military Aircraft in San Diego this August.

THE INSTITUTE'S 36TH SECTION has been organized in Sacramento, California. Official welcome will be extended at the section's inaugural meeting to be held this month.

THE NEW YORK LIBRARY FACILITIES OF THE IAS have been moved to newly refurbished quarters on the second floor at 2 East 64th. The facility will be dedicated as the Lester Durand Gardner Memorial Library in honor of the Institute's indefatigable founder.

EDITOR'S NOTEBOOK: While announcements of our mammoth magazine for May (the Manned Space Stations Issue) have appeared elsewhere, the 'hot news' nature of the Green Sheet permits a rundown that will interest IAS members who have expressed a desire for more State of the Art-type of information, plus those who either must or wish to look to their society's publications for the best and latest technical data. Though the size of the issue is of passing interest (it will contain some 40,000 words) May's A/SE has been planned for seven months with QUALITY in mind. Each author was chosen for us merely by having been selected by the IAS-NASA-RAND National Symposium on Manned Space Stations Committee as a participant in the Symposium (in Los Angeles on the 20th, 21st, and 22nd of next month). Each author has prepared his own Symposium presentation in a form which will get the most important information across to our readers in the shortest reading time possible. Collectively, the articles will present knowledge as it exists in the United States NOW. So here's to good reading for May!—A.B.

DR. JOSEPH V. CHARYK, IAS FELLOW, has been confirmed by Congress as Under Secretary of the Air Force. DR. COURTLAND D. PERKINS, IAS FELLOW, has been appointed by Pres. Eisenhower to succeed Dr. Charyk as Assistant Secretary of the Air Force.

SECTION MEETINGS CALENDAR*

Mar. 8 Los Angeles: Specialists Meeting, 8 pm, IAS Bldg., "Importance of Panel Flutter in Design of Light Weight Structures," Prof. B. Fung, Cal Tech.

Mar. 9 Niagara Frontier: Dinner Meeting, 7 pm, Cornell Aero Lab., "The Delta Wing Story", A. Burstein, Convair-San Diego.

Mar. 9 Atlanta: Dinner Meeting, 6 pm, Buckhead Elks Club, "The Navy Guided Missile Program", RAdm. K. S. Masterson, USN, Off. Ch. of Naval Operations.

Mar. 9 Chicago: Technical Meeting, 7 pm, Illinois Inst. of Technology, "High Temperature Gas Dynamics", Prof. Howard W. Emmons.

Mar. 10 Baltimore: Dinner Meeting, 7 pm, Westinghouse Air Arm Div., "Soviet Military and Political Plans", Herbert S. Dinerstein.

Mar. 10 Boston: Minta Martin Lecture, 8 pm, See Page 1 of Green Sheet.

Mar. 15 Washington: Minta Martin Lecture-Dinner, 6:30 pm, See Page 1 Green Sheet.

Mar. 15 Wichita: Dinner Meeting, 6:30 pm, Innes Tea Room, "Traffic Jam in the Sky" Capt. A. C. Packard, FAA.

Mar. 22 Los Angeles: Specialists Meeting, 8 pm, IAS Bldg., "Closed Ecological Systems for Space Vehicles", George L. Hobby, Jet Prop. Lab., CIT.

Mar. 24 San Antonio: Technical Meeting, 7 pm, Officers Club, Kelly AFB, "Logistic Support", Maj. Gen. L. L. Mundell.

Mar. 29 Washington: Specialists Meeting, 8 pm, Auditorium, National Academy of Sciences, "Automatic Air Navigation-Adaptability to Air Traffic Control", Lt. Col. M. E. Esch, USAF, and A. B. Winick, FAA.

Mar. 31 Los Angeles: Minta Martin Lecture, Dinner, 6:30 pm, see Page 1 Green Sheet

* Items for this section accepted up to seven working days before end of the month.

INTERNATIONAL, NATIONAL, AND JOINT MEETINGS CALENDAR

Mar. 10-11	Flight Propulsion Meeting (Classified), Cleveland, Ohio.
Apr. 20-22	Symposium on Manned Space Stations (cosponsored by NASA and The RAND Corp.), Ambassador Hotel, Los Angeles, Calif.
May 2-4	IRE Aeronautical Electronics Conference (Participation by Dayton Section of IAS), Dayton, Ohio.
May 23-25	National Telemetering Conference (cosponsored by IAS, ISA, ARS, and AIEE), Hotel Miramar, Santa Monica, Calif.
May 25-27	Specialists Meeting, Guidance of Aerospace Vehicles, Boston, Mass.
June 28-Jul. 1	Summer Meeting, Ambassador Hotel, Los Angeles, Calif.
Aug. 1-3	Meeting on Future of Manned Military Aircraft, San Diego, Calif.
Sept. 12-16	2nd International Congress, International Council of the Aeronautical Sciences, Zurich, Switzerland.
Oct. 3-5	Midwestern Conference on Air Logistics, Tulsa, Okla.
Oct. 17-18	CAI/IAS Joint Meeting, Queen Elizabeth Hotel, Montreal, Canada.
Oct. 20-21	Symposium on Hypervelocity Techniques, Denver, Colorado.
Dec. 17	Wright Brothers Lecture, Washington, D.C.
1961	
Jan. 23-25	29th Annual Meeting, Hotel Astor, Times Square, New York.

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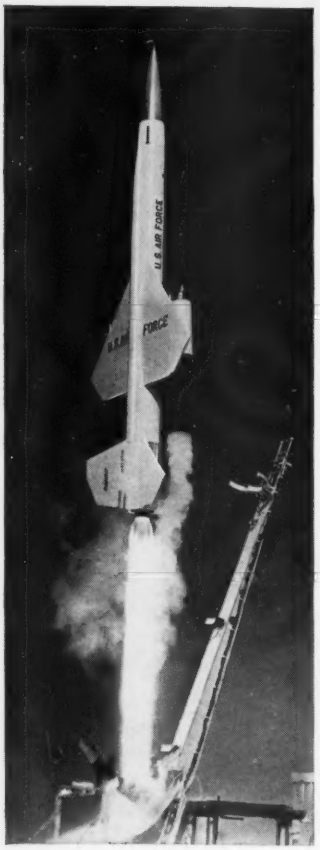

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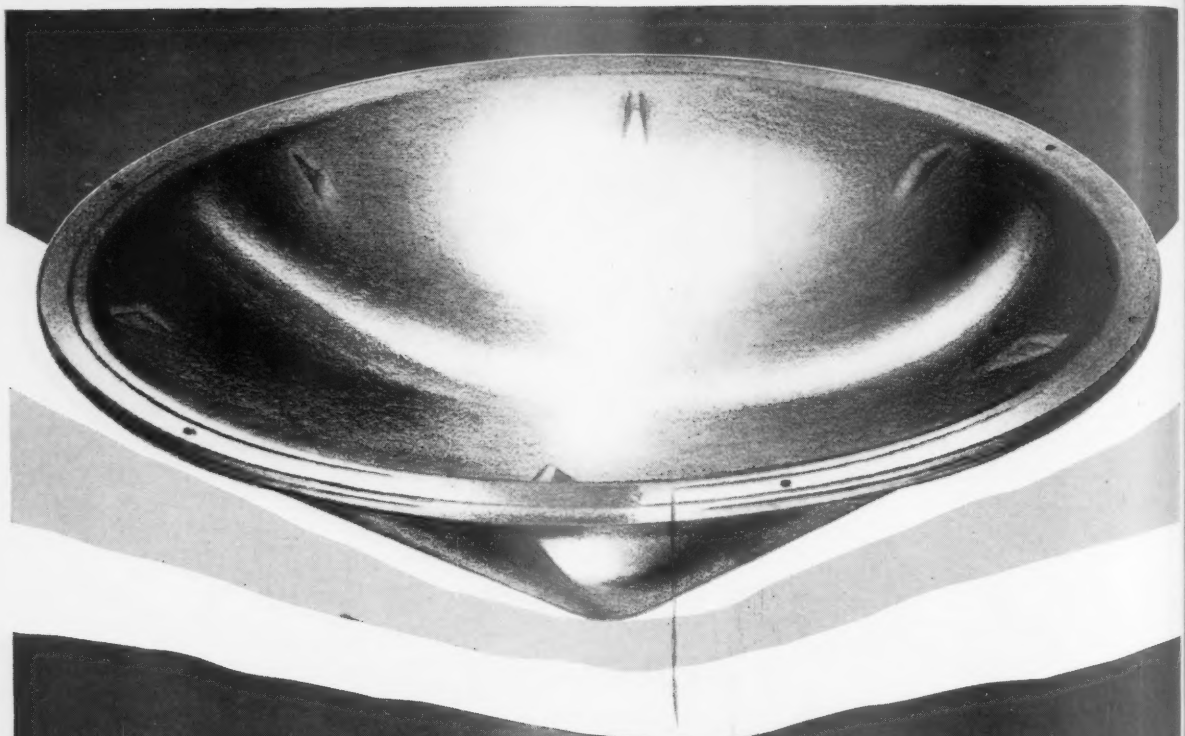

RE-ENTRY SHIELDS

EST. 1883

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- Beryllium in limited production
- Reinforced plastics in development

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LOS ANGELES, CALIFORNIA

IAS News

. . . a record of people and events of interest to Institute Members

Annual Business Meeting of the Institute

Reports of President, Treasurer, and Director

THE TWENTY-EIGHT ANNUAL MEETING of the members of the Institute was held at the Hotel Astor, New York, on January 27, 1960. William Littlewood, President, presided.

Elmer A. Sperry, Jr., Teller, reported that he had received and counted 1,734 valid proxies for voting at the Annual Meeting—a quorum of the voting membership.

The Secretary, on behalf of the Nominating Committee, placed in nomination the following members for election to vacancies on the Council:

Donald L. Putt, President; William Littlewood, Past President; and Victor E. Carbonara, Treasurer; for a term of 1 year each. Western Region—Harold Luskin, Vice-President; Milton U. Clauser, Donald P. Germeraad, Nicholas J. Hoff for a term of 2 years each; Welko E. Gasich and Yusuf A. Yoler for a term of 1 year each. Central Region—Paul H. Dane, Vice-President; Preston E. Dickson and Clyde R. Murtaugh for a term of 2 years each; Peter Altman, Hubert I. Flomenhoft, and Vernon Outman for a term of 1 year each. Eastern Region—Charles Tilgner, Jr., Vice-President; John S. Attinello, Lawrence Levy, and Axel T. Mattson for a term of 2 years each. On motion duly made, seconded, and carried, they were unanimously elected. The following were nominated and elected in like manner to serve on the Nominating Committee for 1960: William Littlewood, Chairman; Wellwood E. Beall, Clark B. Millikan, L. Eugene Root, Raymond C. Sebold, Edward R. Sharp, R. Dixon Speas, and H. Guyford Stever.

The Annual Reports of the President, Treasurer, and Director were read and approved. (See the following pages for the complete reports.)

The Secretary presented a list of honors conferred by the Institute in 1959 as follows: The Octave Chanute Award to John P. Reeder, Chief, Flight Operations Branch, Flight Research Division, Langley Research Center, NASA; the Louis W. Hill Space Transportation Award to James A. Van Allen, Professor and Head, Department of Physics and Astronomy, State University of Iowa; the John J. Jeffries Award to Don Flickinger, Brigadier General, USAF (MC), Assistant for Bioastronautics and Surgeon, Hq. ARDC; the Robert M. Losey Award to Herbert Riehl, Associate Professor of Meteorology, University of Chicago; the Sylvanus A. Reed Award to Karel J. Bossart, Assistant to the Vice-President—Engineering, Convair Division, General Dynamics Corporation; the Lawrence Sperry Award to James E. McCune, Senior Scientist, Aeronautical Research Associates of Princeton, Inc.; the Minta Martin Aeronautical Student Fund-National Paper Awards to: Undergraduate Division—Charlie M. Jackson, Jr., Virginia Polytechnic Institute; Graduate Division—E. Brian Pritchard, Virginia Polytechnic Institute; Doctorate Division—William J. Rae, Cornell University, and Ronald Stearman, California Institute of Technology; and the Wright Brothers Lecturer, Alexander H. Flax, Chief Scientist, United States Air Force, who spoke on "High Temperatures in Hypersonic Flow—Physical Principles and Experimental Techniques."

Honorary Fellowships in the Institute to: American—E. A. Sperry, Jr., formerly Sperry Gyroscope Company; Foreign—E. T. Jones, Deputy Controller (Overseas Affairs), Ministry of Aviation, London. Fellowships in the Institute to: J. V. Charyk, Assistant Secretary of the Air Force; Alfred J. Eggers, Jr., Aeronautical Research Scientist, Ames Research Center, NASA; Vice Adm. John T. Hayward, USN, Deputy Chief of Naval Operations (Development), Navy Department; Lester Lees, Professor of Aeronautics, California Institute of Technology; C. C. Lin, Professor of Mathematics, M.I.T.; Eugene J. Manganiello, Associate Director, Lewis Research Center, NASA; H. J. van der Maas, Professor of Aeronautics, Delft Technological University, Delft; and Lysle A. Wood, Vice-President, Boeing Airplane Company; General Manager, Aero-Space Division.

The Secretary announced the officers of the Institute for 1960 as follows: President, Donald L. Putt; Vice-Presidents, Paul H. Dane, Harold Luskin, and Charles Tilgner, Jr.; Treasurer, Victor E. Carbonara; Director, S. Paul Johnston; Secretary, Robert R. Dexter; and Controller, Joseph J. Maitan.

ROBERT R. DEXTER
Secretary

President's Report—1959

TO HAVE SERVED as IAS President for the year which is ending with the 28th Annual Meeting has been most rewarding and gratifying to me and has, I hope, proved beneficial to the Institute. The principal emphasis throughout 1959 has been on improved and expanded service to the members who are the reason and justification for its existence. Your President has made sincere efforts to be present at as many of the Institute meetings, both national and local, as has been reasonably possible consistent with his other obligations. He has taken great satisfaction in emphasizing contacts with the IAS student groups and in experiencing the great breadth of IAS interests and activities exemplified by its national meetings.

1959 was perhaps most noteworthy as the year of execution of the Constitutional changes which have implemented the previously conceived plan for the establishment of geographic regions and for the ensuring of adequate direct representation by officerships and Council membership from those regions to further enhance the expressed interests of the members in various areas. The plan was previously conceived with praiseworthy vision, was implemented in 1959, and will become effective and valuable in the years to come.

The year has also been noteworthy as the occasion for the 7th Anglo-American Conference held in the northeastern part of the United States and Canada. Our visitors from the Royal Aeronautical Society have announced themselves as

IAS Officers for 1960

STAFF OFFICERS FOR 1960

S. Paul Johnston, Director

Robert R. Dexter, Secretary

Joseph J. Maitan, Controller

PRESIDENT

Donald L. Putt

President United Technology Corp.

VICE-PRESIDENT

Central Region

Col. Paul H. Dane, USAF

Professor of
Thermodynamics
USAF Academy

VICE-PRESIDENT

Western Region

Harold T. Luskin

Staff Assistant to Manager
Satellite Systems, Missiles & Space Div.
Lockheed Aircraft Corporation

VICE-PRESIDENT

Eastern Region

Charles Tilgner, Jr.

Chief Aeronautical Engineer
Grumman Aircraft
Engineering Corporation

TREASURER

Victor E. Carbonara

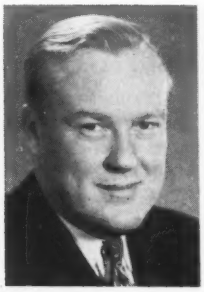
President
Kollsman Instrument
Corporation

Newly Elected Members of the INSTITUTE COUNCIL

EASTERN REGION

John S. Attinello
Asst. to Chief Engr.
Aircraft & Missiles Div.
Fairchild Engine &
Airplane Corp.

Lawrence Levy
President
Allied Research
Associates, Inc.



Axel T. Mattson
Head
Eight-Ft. Tunnel Branch
Langley Research Center
NASA

CENTRAL REGION

Peter Altman
Vice-President
Research & Devel. Div.
Continental Motors Corp.

Preston E. Dickson
Group Engineer
Aerodynamics
Beech Aircraft Corp.

Hubert I. Flomenhoft
Group Leader, Flight Loads
Dynamic Science Sect.
North American Aviation
Columbus Div.

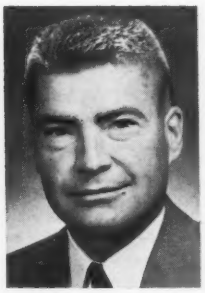
Clyde Murtaugh
Flight Sciences Dept.
Bendix Systems Div.
Bendix Aviation Corp.

Vernon Outman
Chief Technical Engr.
McDonnell Aircraft Corp.

WESTERN REGION

Milton U. Clauser
V-P & Dir., Physical
Research Lab., Space
Technology Labs., Inc.

Welko E. Gasich
Dir., Weapon System
Development Engrg.
Northrop Corp.



D. P. Germeraad
Chief Engrg. Test Pilot
Convair Division
General Dynamics Corp.

Nicholas J. Hoff
Head
Div. of Aero. Engrg.
Stanford University

Y. A. Yoler
Head
Flight Sciences Lab.
Boeing Airplane Co.

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Statement for the Fiscal Year October 1, 1958, to September 30, 1959

Consolidated Balance Sheet and Operating Statement

ASSETS

Unrestricted:		
Cash on Deposit	$151,060	
Accounts Receivable	26,505	
Advances on Intrafund Accounts	41,945	
Deposits and Prepayments	28,851	
Furniture and Fixtures	5,000	
Investments	566,602	
Total Unrestricted Assets		$ 819,963
Facilities (at cost):		
Los Angeles	$429,424	
New York	220,951	
San Diego	176,706	
Total Facilities		$ 827,081
Specific:		
The Sherman M. Fairchild Fund	$ 10,382	
The Flight Test Fellowship Fund	10,124	
The Guggenheim Fund	388,245	
The Louis W. Hill Space Transportation Fund	6,273	
The Paul Kollsman Fund	69,000	
The Vernon Lynch Award Fund	37,696	
The Minta Martin Aeronautical Student Fund	511,767	
The Sylvanus Albert Reed Award Fund	13,632	
The Lawrence Sperry Award Fund	13,483	
The Water-Based Aircraft Fund	20,919	
The Los Angeles Building Operating Fund	25,253	
The New York Building Maintenance Fund	103,989	
The Pacific Aeronautical Library Fund	36,442	
Total Specific Assets		$1,247,205

LIABILITIES AND RESERVES

Accounts and Deposits Payable	$113,902	
Deferred Credits to Income	198,756	
Deferred Income—San Diego Building	12,254	
Deposit—Pacific Aeronautical Library	5,000	
Reserve Accounts	263,759	
Property Fund	827,081	
General Fund—Balance September 30, 1959	226,292	
Total		$1,647,044
Specific Fund Reserves—Principal Balances		$1,247,205

Statement of Income & Expenses

Income:		
Dues and Entrance Fees	$330,553	
Advertising Revenue	267,418	
Subscriptions and Related Accounts	211,197	
West Coast Buildings Revenue	35,672	
Dividends and Interest (unrestricted)	34,481	
Funds Administration	17,400	
Contracts Overhead Offset	14,935	
Miscellaneous	15,028	
Total Income		$926,684
Expenses:		
Publications	$396,921	
Salaries—Administrative, Clerical, & Accounting	193,350	
Libraries and Related Activity	112,378	
West Coast Offices	85,344	
Employees Retirement Fund & Social Security	37,751	
Meetings and Travel	32,542	
Printing, Postage, Communication, and Equipment	29,991	
Building Maintenance	17,600	
Office Supplies and Expense, Insurance	14,008	
Miscellaneous	7,472	
Net Expenses		$927,357
Net Loss		$ 673

highly gratified by the success of the joint meetings and have expressed great appreciation for the courtesies extended to them by company members of the Institute and others who acted as their hosts. My own personal thanks must be expressed to the Institute officers and staff who did such a thorough and capable job in this connection, as well as in all other major activities throughout the year.

The Institute ends the Presidential year in good financial shape with a continually expanding membership of the highest quality, with an ever-increasing breadth of aeronautical and related interests and activities, and with the satisfaction of having conducted a series of valuable local area and national meetings, and can look forward to growth and further successes in the future.

Your retiring President is grateful for the opportunity of having served you throughout this successful year and wishes to congratulate the Institute on the selection of its officers and Council for 1960.

WILLIAM LITTLEWOOD
President

Treasurer's Report—1959

AN EXPANDED program of meetings and intensified Section and student activities, coupled with the never-ceasing increases in material and labor costs, contribute to the continuing fiscal problem with which your society is faced. Under the new Constitution, increasing activity will result from the implementation of the Program Planning Committee, Publication Committee, Aero/Space Technology Panels, and the Regional operating system. Continuous consideration must be given to financing the operations of these new activities to keep costs within reasonable limits.

In the spring of 1957 an estimate of operations for the following 3 years was reviewed by the Council. It predicted a net operational loss of $37,000 in 1959. At that time the Corporate Member dues schedule was revised, and it was estimated that increased revenues from this source would be on the order of $50,000 annually. Shifts in defense spending, mergers, and other factors resulted in a net increase from this source of only $31,000 in 1959. Through economies (principally by reducing publication costs) sufficient savings were developed to overcome the reduced revenue. The Budget presented in the fall of 1958 (and approved by the Council) predicted a "break-even" situation at the end of the past fiscal year.

With all returns in, and all adjustments authorized by the Council made, the operating statement (*q.v.*) shows a net loss of less than $700 on a $1,000,000 operation or about 0.07 per cent. The net cost of general management, meetings, publications, and Kollsman Library operations was $2,667; the Los Angeles Building net loss was $9,314; and the net income of the Pacific Aeronautical Library amounted to $11,308, as a result of an upward adjustment of subscriber service rates.

Over the past years many of the membership services were supported through advertising dollars and reserves accumulated. Unless the income derived from advertising improves substantially, and is maintained, serious consideration must soon be given to looking to other sources to pay for the services offered.

The ARDC renewed its contract with the IAS to continue the compilation of classified and unclassified technical motion picture films produced in the United States. This service is proving to be extremely valuable to research laboratories, Government agencies, and the industry. The International Aeronautical Abstracts contract was also renewed by AFOSR, which regards the work as an excellent source of technical worldwide literature to keep engineers and scientists aware of disclosures in all areas.

An appropriation of $10,000 was authorized by the Council for a study regarding the development of office and auditorium buildings on the Los Angeles property, relating the use of this facility to the long-range requirements of the members in that region. This study is presently under way.

The NASA canceled its office space lease in the Los Angeles Building. The reduced income from this source contributed to the operations loss of the building. The long-term lease with California Western University at the San Diego Building has been canceled by the university as of January 1, 1960. Proposals as to disposition of the building are now under consideration.

The Finance Committee met periodically and recommended stock transactions resulting in capital gains of $9,000 during the year which were transferred to the Capital Investment Contingency Reserve account presently standing at $69,000. The book value of investments as of September 30, 1959, is $1,680,306, and in addition there is an increase of $415,473 in the market value as of that date.

Through our legal counsel the IAS petitioned for and received relief from the payment of New York City sales tax on its purchases. This effected a saving of over $1,000 to date.

The books of account have been examined by Harris, Kerr, Forster and Co., Certified Public Accountants. A copy of their complete report is available to members for review at the national office.

JEROME LEDERER
Treasurer

Director's Report—1959

AS WITH any business enterprise, management's problem is to conserve corporation assets and to manipulate income and outgo so as to produce dividends. In periods of rising costs and reduced income, budget balancing requires constant attention. The results of the past year's operation in the fiscal area are set forth in the Treasurer's Report preceding. But in our kind of business "profit" is not measured in dollars. Surpluses are ploughed back into services. Dividends accrue to members in the form of increased professional knowledge and to industry in the form of better professional people. This report deals mainly with the past year's progress in producing such dividends.

Meetings

Activity in the form of meetings at all levels—national, regional, and local—continued high. The following schedule lists National Meetings, which were IAS organized or in which we participated:

National Meetings

Jan. 26–29	27th Annual Meeting	New York City
Mar. 5–6	Flight Propulsion Meeting	Cleveland
June 16–19	Summer Meeting	Los Angeles
Aug. 20–21	National Specialist Meeting Symposium on ASW (classified)	San Diego
Nov. 2–4	Midwestern Meeting—"New Frontiers of Sciences"	Wichita
Nov. 17–18	Turbine-Powered Air Transportation Meeting	San Francisco
Dec. 17	Wright Brothers Lecture	Washington, D.C.

Cosponsored Meetings

May 25–27	IAS/ISA/AIEE/ARS National Telemetering Conference	Baltimore
Sept. 16–17	IAS/Univ. of Calif.—"Frontiers of Science Engineering"	Los Angeles
Oct. 5–16	7th Anglo-American Aeronautical Conference, IAS-RAeS	New York City

Table 1. Sections and Branches

	1949	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*
Sections	19	23	24	25	26	24	27	27	28	30	35
Meetings	126	144	168	181	237	241	267	275	320	350	359
Members	5,718	6,436	7,143	7,379	8,408	8,411	9,043	9,837	11,120	12,175	13,793
Student Branches	67	70	71	71	69	71	73	74	73	78	78
Members	3,958	3,395	3,006	2,796	2,672	3,110	2,984	3,908	4,274	4,400	4,557

Participating Meetings

Apr. 5–10	5th Nuclear Congress	Cleveland
May 4–6	IRE National Aeronautic Electronics Meeting	Dayton
June 11–13	Heat Transfer and Fluid Mechanics Institute	Los Angeles
Sept. 9–11	Midwestern Conference on Fluid and Solid Mechanics	Austin

International

In October the Seventh Anglo-American Aeronautical Conference with The Royal Aeronautical Society of Great Britain took place in New York City and vicinity. For the first time the Canadian Aeronautical Institute participated. The final 3 days of the program were held in Canada under CAI auspices. By joint action of the RAeS and IAS Councils, the organization of the Eighth Anglo-American Aeronautical Conference in England in 1961 was authorized.

In addition to the collaboration with Canada outlined above, the usual exchange arrangements with the CAI were maintained throughout the year.

Planning for the 1960 ICAS meeting in Zurich accelerated during the year. IAS Secretary Dexter went to Zurich in April to meet with the Program Committee and to lay the ground work for the technical sessions. The Director attended an ICAS Executive Committee meeting in Paris in June, and Mr. Dexter visited Zurich again in September following his attendance at the AGARD meeting in Aachen to finalize local arrangements. Work on the technical program has been continuous during the last 6 months of the year.

Sections

For the 14th consecutive year, all aspects of Section operation reached new highs (see Table 1). Section membership increased by over 1,500 in 1959 and now represents 87 per cent of total IAS membership. New Sections were organized in South Florida, New Mexico, Connecticut, Omaha, and the Great Salt Lake area, increasing the total to 35. Negotiations are under way for the establishment of Sections in Sacramento and Birmingham.

Two meetings of Section Chairmen were held, one in New York during the Annual Meeting and one in Los Angeles during the Summer Meeting. Six issues of the Section Officers' *Newsletter* were published in 1959.

The Fourth Minta Martin Lecture was presented in 1959 at meetings involving the Boston, Washington-Baltimore-Hagerstown, and Los Angeles Sections.

Student Activities

Present student membership enrollment in 78 branches is 4,577. Four new student branches were established—Arizona State University, University of Arizona, U.S. Air Force Academy, New York University-Evening. Two branches were dropped. A charter for each student branch was prepared and mailed. The IAS student branch newsletter was redesigned, retitled *IAS Student News*, and its editorial content expanded.

In the spring of 1959 seven Regional Student Conferences were held, sponsored by the Minta Martin Aeronautical Student Fund—one each in Ithaca, N.Y.; Atlanta; Fort Worth; St. Louis; Washington, D.C.; Detroit; and Los Angeles. Sixteen technical papers which won First Prizes in the 1959 Conferences were published in the *1959 First Award Papers;* 750 copies have been distributed to Sections, Branches, Corporate Members, the IAS Council, schools, libraries, and interested individuals. Four National Awards—two doctorate (first-place tie), one Master's, and one undergraduate—were awarded in 1959 and presented in early 1960.

A new edition of the IAS Guidance Manual/Career Booklet was researched, prepared, and retitled *Your Career as an Aero/Space Engineer*. Approximately 17,000 copies of the original career booklet, *Your Career as an Engineer in Aviation*, were mailed, exhausting the supply. It is planned to distribute 100,000 copies of the new booklet through our own channels. Efforts will be made to secure additional financing for reprinting and for more extensive distribution.

The IAS Flight Test Engineering Fellowship for 1959 was awarded to Fox Conner of Lockheed. A new Flight Test Fellowship folder was prepared and mailed.

All films in the New York Library were rehabilitated. An IAS leader was prepared and attached to each print. A new film list was prepared (abstracting 243 titles) and mailed. All titles in the New York Library were recatalogued and the loan system reorganized to make it less time consuming.

A total of 21 new titles was obtained for the New York Library, and permission was granted to list 23 others as being available from respective producers. There are currently 76 individual titles (and some duplicate prints) in the New York Library. Copies of the *Air Force Film Manual* listing all their titles were obtained and mailed to all Student Branches. A tape library was started on a trial basis. So far eight tapes of the various speeches given at IAS meetings are available.

Publications

Throughout 1959, the Staff continued in its efforts to improve the quality and services of all IAS publications. A readership survey was conducted in May to determine the fields of interest of our members and to serve as a guide to the editors and publisher. As a result, certain editorial features of the magazines were expanded, others reduced. Further changes along these lines are planned for 1960, with the assistance and advice of the new Publications Policy Committee provided by the revised By-Laws.

While advertising and subscription revenues again failed to cover the complete costs of AERO/SPACE ENGINEERING, the deficit for this year was approximately one third that of 1958. The loss represents, almost exactly, the cost of printing and publishing the International Abstracts section of the magazine, which is the Institute's contribution to the Air Force sponsorship of this important job.

The prospects look good for slightly more advertising revenue in 1960, and it is anticipated that the *A/SE* operation will at least break even during the year. Meanwhile, every effort is being made to increase the editorial content and usefulness of the book. Two special issues are being planned for 1960—the first one in May on "Manned Space Stations." This will contain some 39 exclusive articles, covering all aspects of the subject, and will represent the most comprehensive collection of papers on space problems yet published under a single cover. The second "special" will be the IAS *Roster of Members* issue, appearing in August.

In order to catch up partially with an ever-increasing backlog of excellent papers, alternate issues of the JOURNAL

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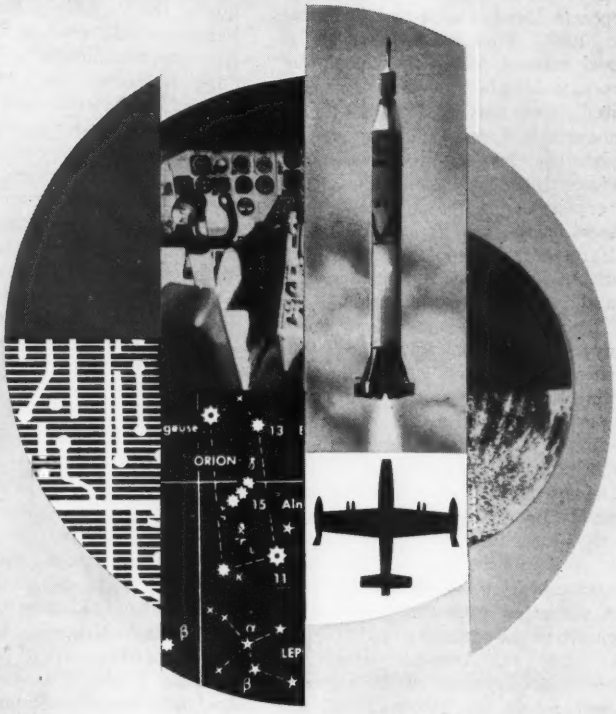

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OF THE AERO/SPACE SCIENCES were expanded from 64 to 80 pages this year. It is planned to maintain a regular 80-page issue each month throughout 1960, and a possible further expansion is hoped for 1961.

The 1960 AERO/SPACE ENGINEERING CATALOG will appear in March. Some 500 new product headings and 10,000 listings have been added to the Directory Section of this issue. These additions, plus an improvement in the method of printing, make the 1960 CATALOG the most complete and useful products directory in the field. Immediately upon publication, 7,500 copies will be distributed to the engineering and procurement departments of all prime manufacturing companies and Government agencies.

During the course of 1959, publication of papers and preprints under the Sherman M. Fairchild Fund continued. Some 47,409 copies of all papers and 152 new titles were produced and distributed.

Library Services—New York

Library services to the IAS membership again showed an increase over the previous year. Of the total inquiries received, some 90 per cent were directed to the technical library and about 10 per cent to the historical library.

In the technical library, circulation of periodicals, reports, books, and papers were 8.7 per cent higher than in 1958. Corporate Member use rose 23 per cent over 1958. This lending service is offered without fee to individual and Corporate Members of the IAS in the United States and in Canada. Somewhere near half of the publications lent fell into the "hard-to-obtain" category. Photocopy prints made on order were up 26 per cent against the previous year.

Accessions showed an increase chiefly with respect to report literature, of which 3,183 were received from governmental and civilian organizations in the U.S. and abroad. The cooperation of many governments, publishers, universities, and individual authors in sending their publications for abstracting purposes and on exchange makes it possible to keep expenditures for new publications to a minimum.

The abstracts section, headed by Miss Irene W. Bogolubsky, increased coverage by 21 per cent for a total of 8,915 citations published in AERO/SPACE ENGINEERING. Coverage thereby kept pace somewhat with the still growing literature in the aerospace field. To do this, while still keeping within the printed space limits set earlier, required an increase in the percentage of unannotated citations and a still higher selectivity with respect to the technical level of the material abstracted. Forty-four per cent of the coverage represented publications originating outside the U.S. Abstracts of material from Communist-bloc sources totaled 1,145 items, of which 909 were in the Russian language. The publication of International Aeronautical Abstracts, which has appeared as a special insert in AERO/SPACE ENGINEERING since January, 1956, continued to receive support from the Air Force Office of Scientific Research of the Air Research and Development Command, USAF.

Table 2. Membership by Calendar Year

	12/31/57	*12/31/58*	*12/31/59*
Temporary Honorary Members	16	19	20
Honorary Fellows	32	32	33
Fellows	213	215	222
Associate Fellows	1,240	1,475	1,685
MEMBERS	5,778	6,402	6,976
Associates	6,074	6,508	6,782
Total Graded	13,353	14,651	15,718
Student Members	4,274	4,400	4,557
Totals	17,627	19,051	20,275

The valuable exchange of advance manuscript abstracts continued in effect between the IAS and the British Ministry of Aviation office, charged with publication of *Index Aeronauticus*. Abstract cards were also received regularly from the Zentralstelle der Luftfahrtdocumentation, Wissenschaftliche Gesellschaft für Luftfahrt, e.V., in Munich, Western Germany.

Sales of the AERONAUTICAL ENGINEERING INDEX for 1957 (an annual compilation of all abstracts published during the year), which was issued in February, 1959, amounted to 700 copies. Receipts continued to be ahead of direct production costs by a favorable amount. Editorial and production work was continued during the year on the 1958 and the 1959 volumes.

The historical section, operated by Miss Elizabeth B. Brown, continued to serve many outside organizations in providing biographical, statistical, and historical information not easily available from other sources. Users included advertising agencies and artists, writers, graduate students, and representatives of leading newspapers, magazines, and other communications media. Approximately 1,700 new photographs were added to this collection during the year.

A major improvement in the physical arrangement of the New York Library was started late in 1959. By consolidating certain exhibits and exhibit areas and by putting certain items out on semipermanent loan to such organizations as the Smithsonian Institution and the Manhattan High School of the Aviation Trades, the entire second floor has been made available for Library purposes. Through the generosity of an old friend of the Institute, a completely new steel bookstack installation has been purchased and installed on the second floor, and the entire area refurnished and relighted. Space in the basement formerly used by the Library will be opened up for much-needed expansion of our printing and mailing facilities. The completion of this project was delayed by steel shortage during the strike, but all material is now on hand, and the work should be completed early in 1960. In accordance with the wishes of the man who made this possible, the facility will be dedicated upon its completion as the Lester Durand Gardner Memorial Library.

Pacific Aeronautical Library

The demands by industry on our Los Angeles Library facility increased steadily during 1959. Mrs. Steinmetz reports that services rendered to subscribers were the highest in history. The 68 regular member plants were supplied with 44,500 separate items. In order to cover the increasing range of subjects now of interest, the PAL, in turn, borrowed some 7,500 items from local university libraries in the area. Over 10,000 articles were covered in the *Uniterm Periodical Index*.

Last year, because of the greatly increased demands on the small staff and the rising costs of all goods and services, the PAL incurred a small deficit. The Library Advisory Committee authorized an increase in subscription rates early in the year. As a result, the operation ended this year "in the black," after charging off last year's deficit.

Membership

Membership is our main barometer of satisfactory performance. In the December, 1959, Editorial "Let's Look at the Record" in AERO/SPACE ENGINEERING, we charted the Institute's growth. For over almost 30 years increases have been steady and stable. Although we netted an increase of over 1,000 members, 1959 has not been our best membership year. There were some decreases in individual membership inquiries, in new applications received and processed, and in former members seeking reinstatement. The numbers are not significant enough, however, to indicate any appreciable trend away from the norm. It would not seem unreasonable to attribute this to uncontrollable external causes such as

Flames swept across the open plains as the Mongol hordes ran in terror from the "arrows of flying fire". When the smoke had cleared the Chinese had won the battle of Pienking with the first rocket.

Missiles have become greatly more sophisticated since this crude unguided arrow was propelled by gunpowder packed in an open-ended bamboo tube. Today, as a vital part of one of the world's largest electronics companies, Raytheon's Missile Systems Division is making significant contributions to the art of missilry. The exciting new Pin Cushion Project for selective missile identification, the constantly advancing Navy's air-to-air SPARROW III and Army's HAWK are examples of their outstanding creative work.

We are seeking highly creative people to maintain Raytheon's leadership in this challenging field. For these people, Raytheon's Missile Systems Division creates a climate for talent — perhaps *your* talent.

MISSILE: 13th CENTURY

ENGINEERS: immediate openings in Data Handling — Circuit Design — Packaging—Electro-Mechanical Design—Systems Test — Test Equipment Design — Systems Analysis — High Power Radar Design — Microwave Tube Application — High Voltage Power Supply — Modulators — Microwave Design — Systems Design — VHF Circuit Design — Operations Analysis — Radar Systems and Mathematicians.

Please apply to Mr. W. F. O'Melia, Employment Manager, Bedford Laboratory, Missile Systems Division, Raytheon Company, Bedford, Massachusetts.

RAYTHEON MISSILE SYSTEMS DIVISION

... creates a climate for talent.

the waves of industry layoffs which occurred throughout the country this year. This view is bolstered by the fact that the number of members dropped is exactly the same as last year's. The statistics for the past 3 calendar years are given in Table 2.

Facilities

Apart from the changes in process for the rearrangement of the Second Floor to accommodate the Library and the plans for expanding our printing and mailing facilities into basement space presently occupied by bookstacks, no major changes were made (or are contemplated) in the New York Building. Our normal program of continuous maintenance has been in effect. Also a major "clean-up" of accumulated surplus books and paper from basement and attic areas was carried out in the spring. A considerable tonnage of old material was disposed of at that time.

In Los Angeles continuing effort has been under way to develop additional income to meet rising expense. This, and other matters relating to this facility, are touched upon in the Treasurer's Report (*q.v.*). The special situation pertaining to the San Diego facility is discussed in that Report also.

General

As reported by the President, the organizational changes first proposed in the fall of 1958 were agreed upon and formalized in a revision of the Institute's Constitution and By-Laws. The proper implementation of these changes is the task facing the Officers and Council in the next year or two. No particular difficulties are anticipated.

We are very fortunate in having a strong Council and an able and interested group of Officers at this particular time. We of the Staff will, of course, exert every effort to carry out the policies laid down by the Council in effecting a smooth transition from old to new programs.

In approaching the end of my 14th year as your Director, I wish to record my profound thanks and appreciation to the loyal men and women of the Staff whose daily labors have brought this organization to the stature it enjoys today among scientific societies.

S. PAUL JOHNSTON
Director

✦ ✦ ✦

RASES First Annual Meeting

The Republic Aviation Society of Engineers and Scientists (RASES), an organization founded at Republic Aviation Corporation's Long Island plant early in 1959, held its first annual meeting on December 9 in Huntington, L.I.

The meeting, attended by more than 300 engineering and scientific personnel of Republic's Engineering, Missiles and Research, and Development Divisions, featured guest speaker Alexander Kartveli, Vice-President of Research and Development for Republic and included the installation of the society's officers for 1960.

Mr. Kartveli, a Fellow of the IAS and a member of AERO/SPACE ENGINEERING's Editorial Advisory Committee, Design, Structures and Materials Panel, discussed some of the challenging problems that the aerospace age presents to the aviation industry. He stressed the area of manned aircraft which will be increasingly emphasized, rather than de-emphasized as is popularly assumed.

RASES officers for the coming year are President, Arthur Bertapelle (MIAS); Vice-President, Norman Grossman (AFIAS); Finance Chairman, Theodore Dinella (MIAS); Meeting Chairman, Stafford Beach, Jr. (MIAS); Secretary, Henry Kleindienst (MIAS); Publicity and Publications Chairman, Martin Schmitt (MIAS); Membership Chairman, Donald Weisinger; Structures Division Chairman, Herman Axelrod (MIAS); Systems Chairman, William Vetter; and Fluid Mechanic Chairman, Jung Chung (MIAS).

The primary function of this group, whose membership is composed predominantly of IAS members, is to aid and encourage the professional and technical growth of engineers and scientists at Republic.

Discussing proposed manned space vehicle at RASES First Annual Meeting are (*left to right*) J. Cravero, Chief Engineer—Production; Arthur Bertapelle (M); I. Singer (M), Past-President, RASES; Alexander Kartveli (F); C. E. Pappas (M), Assistant to Vice-President, R&D. All are Republic personnel.

Wright Brothers Trophy Awarded to IAS Member

William P. MacCracken, Jr., a founder member of the Institute of the Aeronautical Sciences and a pioneer in aviation legislation, was awarded the 1959 Wright Brothers Memorial Trophy. The trophy, given annually by the National Aeronautic Association for "significant public service of enduring value to aviation in the United States," was presented to Mr. MacCracken at the Annual Wright Brothers Memorial Dinner in Washington, D.C., on December 17.

Named an Elder Statesman of Aviation by the NAA in 1955, Mr. MacCracken's nomination for the Wright Brothers Trophy read, "[He] has been a driving influence in the evolution of the law of the air and has, throughout his life, worked with great vision and ability in providing a sound legal foundation for the development of civil and commercial aviation in America. His long record of unselfish service is truly significant and of enduring value to aviation."

Scientist Honored for Inertial Guidance Research

Dr. Charles S. Draper (HF) was awarded the 1959 William Procter Prize for Scientific Achievement in Chicago on December 29 at a luncheon held during the annual meeting of the American Association for the Advancement of Science. The $1,000 prize, awarded by the Scientific Research Society of America (RESA) and Sigma Xi, honorary science fraternity, was presented by Dr. Edward R. Weidlein, Chairman of RESA. It is given annually to a distinguished natural scientist in recognition of notable accomplishment in scientific research or in the administration of such research. Dr. Draper is well known for his research on advanced inertial guidance systems.

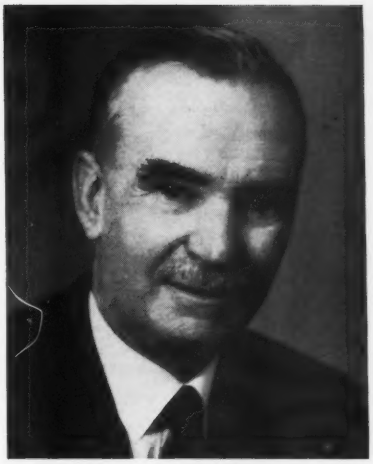
Following the award ceremony, Dr. Draper, who is Director of the M.I.T. Instrumentation Laboratory and Head of its Department of Aeronautics and Astronautics, was principal speaker at the luncheon.

(*IAS General News, Continued on page 26*)

AMERICAN HONORARY FELLOW
Elmer A. Sperry, Jr.

Honorary Fellows for 1959

Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. Not more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellow in any one year.



FOREIGN HONORARY FELLOW
E. T. Jones

Fellowships in the Institute—1959

Fellows of the Institute of the Aeronautical Sciences shall be those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering.

- **Joseph V. Charyk**
  Under Secretary of the Air Force

- **Alfred J. Eggers, Jr.**
  Aeronautical Research Scientist
  Ames Research Center, NASA

- **Vice Admiral John T. Hayward, USN**
  Deputy Chief of Naval Operations
  (Development), Department of the Navy

- **Lester Lees**
  Prof. of Aeronautics, Guggenheim Aeronautical Lab.
  California Institute of Technology

- **C. C. Lin**
  Professor of Mathematics
  Massachusetts Institute of Technology

- **E. J. Manganiello**
  Associate Director
  Lewis Research Center, NASA

- **H. J. van der Maas**
  Prof. of Aeronautics, Delft Technological Univ.
  The Netherlands

- **Lysle A. Wood**
  Vice-President, Boeing Airplane Co.
  General Manager, Aero-Space Div.

IAS Awards for 1959

Brig. Gen. Don D. Flickinger, USAF (MC)
Asst. to Comdr., ARDC, for Bioastronautics, and Command Surgeon

The John Jeffries Award

This award honors the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785, and on a previous flight made the earliest recorded scientific observation from the air. The award was established by the IAS in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine.

Presented to BRIG. GEN. DON D. FLICKINGER, USAF (MC)

"For outstanding contributions to the advancement of aeronautics through medical research."

Don D. Flickinger, M.D., Brigadier General, USAF Medical Corps, was born November 26, 1907, in Erie, Pa. His 25 years of outstanding medical service in the Armed Forces include many notable contributions to the advancement of the aerospace sciences through medical research. General Flickinger was a prime participant in the development and establishment of criteria currently in use for the selection of space crews (including the Mercury Astronauts) and in the development of equipment for environmental control in promotion of human space activities.

Now Assistant to the Commander, ARDC, for Bioastronautics, and Command Surgeon, General Flickinger received his M.D. from Stanford University Medical School in 1933, a Medical Corps commission in 1934, and his flight surgeon's wings in 1937. He has shown outstanding leadership in numerous assignments in aviation medicine and has contributed over 20 papers to medical and aeromedical literature—his four most recent publications dealing specifically with biomedical aspects of space flight. Among his more recent efforts is the organization of human factors research to integrate biomedical work of the Air Force with that of industry, universities, and technical agencies.

General Flickinger's pre-eminence is evidenced by his many awards and his active participation on a number of high-ranking committees devoted to his special field. A leader in bioastronautics and space travel research, General Flickinger has, throughout his career, initiated and participated in endeavors that have made significant contributions to the life sciences in space and fringe-of-space activities.

Herbert Riehl
Professor of Meteorology
University of Chicago

The Robert M. Losey Award

Established in 1940, this annual award honors the memory of Capt. Robert Moffat Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. The award carries an honorarium.

Presented to HERBERT RIEHL

"In recognition of outstanding contributions to the science of meteorology as applied to aeronautics."

Herbert Riehl, Ph.D., Associate Professor of Meteorology at the University of Chicago, has carried out studies of the jet stream and tropical meteorology which have made him a recognized authority in these fields. He is responsible for much of our present knowledge of the jet stream and its relation to weather systems and the long planetary waves of the general circulation.

Born in Munich, Germany, Dr. Riehl received his early education in Germany before emigrating to the United States. Receiving an M.S. degree from New York University in 1942, he joined the Department of Meteorology at the University of Chicago as an Instructor that same year. He was awarded a Ph.D. by the University of Chicago in 1947.

During World War II, Dr. Riehl served as a civilian with the Office of Scientific Research and Development. He has also been a consultant for the U.S. Army, Navy, Air Force and Weather Bureau.

When air operations extended into the tropics in World War II, it was realized that the normal mid-latitude forecasting techniques were inadequate. With this in mind, Dr. Riehl was granted a one year's leave of absence from the University of Chicago in 1947 to serve as Director of the Institute of Tropical Meteorology in Puerto Rico. In this capacity, Dr. Riehl began studies which have led to much of our current understanding of the meteorology of the tropics. He is considered by many as the leading authority in this country on tropical meteorology. Dr. Riehl has made many important contributions to our knowledge of the dreaded hurricanes which are of immeasurable importance to the safety of air operations in the tropics.

Karel J. Bossart
Asst. to Vice-President, Engineering
Convair, Div. of General Dynamics Corp.

The Sylvanus Albert Reed Award

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the IAS, made an endowment to the Institute in 1933 to provide an annual award to be presented for a notable contribution to the aeronautical sciences, resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics. The award consists of a certificate and an honorarium.

Presented to KAREL J. BOSSART

"For significant contributions to the design and development of the Atlas Intercontinental Ballistic Missile."

Karel J. Bossart, Assistant to the Vice-President—Engineering, of Convair, a Division of General Dynamics Corp., has technical responsibility for all of Convair's missile programs. He has nursed Convair's missile project through its growing pains to its present important roles in the nation's space exploration and defense programs.

Born February 9, 1904, in Antwerp, Belgium, Mr. Bossart graduated from Brussels University in 1925 with a degree in mining engineering. He came to the United States that same year and entered Massachusetts Institute of Technology where he received an M.S. in Aeronautical Engineering 2 years later. Working in the aircraft industry in the East until early 1941, Mr. Bossart joined Consolidated Vultee's (now Convair) Downey Division as Chief of Structures. Since 1946 he has been engaged in rocket research, supervising projects that developed the MX-774 research rocket and the Atlas. Designers under him conceived and developed the MX-774, which introduced innovations that now are almost universal in large missile design.

Mr. Bossart kept ballistic missile studies alive and his design group intact with limited company funds between 1947, when Defense Department cutbacks took effect, and 1951, when Convair was awarded a new contract. By 1953, his group had developed what is essentially the present Atlas design.

A United States citizen since 1936, Mr. Bossart is often referred to as the "Father of the Atlas." He has been the recipient of a number of honors in recognition of his accomplishments.

James E. McCune
Senior Scientist
Aeronautical Research Assoc. of Princeton, Inc.

The Lawrence Sperry Award

This award was endowed in 1936 by the sister and brothers of the late Lawrence Burst Sperry, pioneer aviator and inventor, who was drowned in 1923 at the age of 31 after a forced landing in the English Channel. The certificate and honorarium are presented annually for a notable contribution made by a young man to the advancement of aeronautics.

Presented to JAMES E. MCCUNE

"For outstanding contributions to the theory of flow in axial turbomachinery and to the theory of magnetoaerodynamics."

James E. McCune, Ph.D., has in two important papers shown for the first time the true relationship between the three-dimensional flow in an axial compressor and turbine and the two-dimensional "cascade" flow commonly used to represent it. This work not only provides a fundamental understanding of this important class of flow problems, but also furnishes practical procedures for evaluating three-dimensional effects in any particular region. This investigation covers subsonic, transonic, and supersonic flow situations and shows vividly the effects of changes from one regime to the other. In particular, Dr. McCune proved that three-dimensional transonic flow differs essentially from the corresponding cascade approximation. His results provide essential information concerning both the design of transonic compressors and the simulation of transonic flow through blade rows.

In another series of papers, Dr. McCune has investigated the effects of magnetohydrodynamic interactions in aerodynamic flows and especially has shown the grossly different character of these interactions in different ranges of the magnetic Reynolds number and for different field geometries.

In both of these fields of research, Dr. McCune's contributions show originality, analytical ability, and thoroughness to a degree exceptional in one of his age and experience.

Dr. McCune graduated in 1953 from Carnegie Institute of Technology with a B.S. in Mechanical Engineering. Entering Cornell University's Graduate School of Aeronautical Engineering as a National Science Foundation Fellow, he was awarded his Ph.D. in February 1958. From September 1957 until June 1959, he was Research Associate and then Instructor in Aeronautical Engineering at Cornell. He is now Senior Scientist of Aeronautical Research Associates of Princeton, Inc.

IAS Awards (*continued*)

James A. Van Allen
Professor and Head
Dept. of Physics and Astronomy
State University of Iowa

The Louis W. Hill Space Transportation Award

This award is in recognition of research in any or all of the fundamental sciences relating to space travel or space technology (e.g., take-off, navigation, environmental conditions, biological and psychological factors, re-entry, etc.). Established in 1958, it is administered by the IAS through a Board of Award on behalf of the Louis W. and Maud Hill Family Foundation of St. Paul, Minn. This honor carries with it a monetary award of $5,000 to an individual, or up to $10,000 in the event of a team contribution.

Presented to JAMES A. VAN ALLEN

"By combining simple and direct techniques with great ingenuity, he established beyond doubt the existence, intensity, and extent of the radiation belts above the earth's surface that now carry his name."

James A. Van Allen, Ph.D., Professor and Head of the Department of Physics and Astronomy of the State University of Iowa since 1951, is well known for his studies of radiation belts in space, known as the Van Allen Belts. The results of these studies have contributed immeasurably to man's knowledge of the factors with which he must contend in space exploration.

Born in Mt. Pleasant, Iowa, he received his B.S. in Physics from Iowa Wesleyan College in 1935 and his M.S. and Ph.D., the latter in 1939, from the State University of Iowa.

Beginning his professional career at the Carnegie Institution of Washington, he joined the Applied Physics Laboratory of Johns Hopkins University in 1942, remaining until 1950 with a 4-year interruption for service in the Naval Reserve. During his tenure at APL, he supervised the high-altitude research group and proximity fuze unit. In this capacity he engaged in high-altitude experiments in cosmic rays, atmospheric ozone, geomagnetic field, ultraviolet solar spectroscopy, and high-altitude photography of the earth, pioneering in the use of V-2 rockets for this work. He supervised the development of the Aerobee rocket and its use for similar research. This involved organizing and leading the first two of a series of expeditions for scientific research to various parts of the globe.

William J. Rae

Ronald Stearman

IAS Minta Martin National Student Awards

The Minta Martin Aeronautical Student Fund was established by the late Glenn L. Martin in honor of his mother who encouraged him in his aviation pursuits. It is administered by the IAS to encourage aeronautical engineering education. This is accomplished in part through several annual regional student conferences where students have the opportunity to present original technical papers in competition for cash awards. From among the first-prize graduate and undergraduate papers of all conferences, national award winners are chosen by a board of eminent scientists and engineers. The winners receive engraved plaques for outstanding achievement, duplicates of which are presented to their universities.

Presented to

WILLIAM J. RAE and RONALD STEARMAN:
cowinners, Doctorate Division
E. BRIAN PRITCHARD: Master's Division
CHARLIE M. JACKSON, JR.: Undergraduate Division

Competition in the Doctor's Division resulted in a tie this year between William J. Rae, Cornell University, and Ronald Stearman, California Institute of Technology.

Dr. Rae is now employed by Cornell Aeronautical Laboratories, Inc. His paper, "Viscous Effects in Steady, Two-Dimensional, Potential Flow at Supersonic Speed," won the

(*Continued on page 27*)

E. Brian Pritchard

Charlie M. Jackson, Jr.

Manned Space Stations Symposium to Hear Ramo on April 20; Guidance, Military Aircraft Meetings Added to Year's Agenda

Merits of Free Enterprise in Space Programs to Be Evaluated

Simon Ramo, Executive Vice-President of Thompson Ramo Wooldridge Inc., will be banquet speaker at next month's IAS-NASA-RAND Manned Space Stations Symposium. The dinner will be held in the Ballroom of Los Angeles' Ambassador Hotel the night of Wednesday, April 20. Dr. Ramo, a Fellow of the Institute, is an acknowledged leader in research and development in connection with space technology. The subject of his discussion will be, "Can Free Enterprise Launch Space Platforms?"

The technical portion of the program for this meeting has had one addition, as well as several substitutions. The additional paper, "The Military Test Space Station," by Col. Lowell B. Smith, USAF, Chief, Space Systems Office, ARDC, Wright Air Development Division, is scheduled for the April 20 morning session on Current Status.

The last paper in the afternoon session of that same day, Space Station Design Concepts, is now, "The Economic and Logistic Aspects in the Design of a Manned Space Station," by Joseph H. Doss, Manager, Design and Systems Integration, Aero-Space Div., Boeing Airplane Co. On April 22, the next to last paper in the morning Attitude Sensing and Control session has been changed to "Attitude Control of a Space Vehicle by a Gyroscopic Reference Unit," by Marvin L. Chatkoff, Staff Engineer, and Lewis G. Lynch, Systems Engr., Missile Development Lab., Honeywell Aeronautics Div., Minneapolis-Honeywell Regulator Co. The Power Sources session, also on the morning of April 22, will have as its next-to-the-last paper, "Integrated Thermodynamic Systems for Manned Space Stations," by Michael G. Del Duca, Senior Engineering Specialist, Andrew D. Babinsky, Research Engineer, and Floro D. Mirabaldi, Staff Consulting Engineer, Research and Engineering Requirements-Tapco Group, Thompson Ramo Wooldridge Inc.

Simon Ramo
Symposium Banquet Speaker

Guidance Meeting Program Outlined

A general session outline has been established by the Technical Program Committee for the Specialists Meeting on Guidance of Aerospace Vehicles, scheduled for May 25–27, in Boston, Mass. Session titles and their arrangement have been agreed upon as follows: Wednesday, May 25—morning, Satellite Rendezvous; afternoon, Mechanization Techniques; Thursday, May 26—morning, Attitude Control; afternoon, Special Problems in Guidance and Control; and Friday, May 27—morning, Interplanetary Guidance.

Future of Manned Military Aircraft

An already substantial meetings calendar for the coming year has been made even more notable by the addition of a meeting on the Future of Manned Military Aircraft. Scheduled for August 1–3, it will be held in San Diego, Calif.

Previously announced meetings, in addition to those mentioned above, are this month's Flight Propulsion Meeting in Cleveland, Ohio; participation by the IAS in the IRE Aeronautical Electronics Conference in Dayton, Ohio, May 2–4; cosponsorship of the National Telemetering Conference in Santa Monica, Calif., May 23–25; Summer Meeting in Los Angeles, Calif., June 28–July 1; Second International Congress of the International Council of the Aeronautical Sciences (ICAS) in Zurich, Switzerland, September 12–16; Midwestern Conference on Air Logistics in Tulsa, Okla., October 3–5; CAI-IAS Joint Meeting in Montreal, Canada, October 17–18; Symposium on Hypervelocity Techniques, Denver, Colo., October 20–21; and The Wright Brothers Lecture in Washington, D.C., on December 17.

* * *

IAS Minta Martin National Student Awards

(*Continued from page 26*)

Doctorate Division award at the Northeastern Conference. Cowinner in this division, Ronald Stearman, received his B.S. in Mechanical Engineering from Wichita University. Now employed at C.I.T., his paper, "Small Aspect Ratio Membrane Flutter," was read at the 1959 West Coast Conference.

Master's Division winner is E. Brian Pritchard, who received his B.S. and M.S. in Aeronautical Engineering at Virginia Polytechnic Institute. He is now an Aeronautical Research Engineer with NASA's Langley Research Center.

Charlie M. Jackson, Jr., who received his Bachelor's degree in Aeronautical Engineering at V.P.I., is the winner in the Undergraduate Division. He, too, is an Aeronautical Research Engineer at NASA's Langley Research Center.

Both Mr. Pritchard's paper, "The Stability of Several Missile Nose Configurations in Hypersonic Flow," and Mr. Jackson's, "Laminar Boundary-Layer Control by Magnetogasdynamic Techniques," were read at the Southeastern Conference last April.

The awards were presented at a luncheon held at the Twenty-Eighth Annual Meeting, with duplicates of the plaques presented to each winner's IAS Student Branch Faculty Adviser.

TCEA Offers One-Year Course

The Training Center for Experimental Aerodynamics, Rhode-Saint-Genèse, Belgium, is now receiving applications for entry from graduate engineers and scientists for the one-year diploma course in experimental aerodynamics for the academic year October 3, 1960, to July 1, 1961. The Center, which was founded in 1956 as an international institution under the chairmanship of Professor Theodore von Kármán for training in experimental aerodynamics, has a well-equipped range of modern wind tunnels in its laboratories near Brussels.

There are no fees for this course and a number of student fellowships to cover living expenses are available. Students are required to be fluent in either English or French and citizens of one of the NATO nations.

Further information and application forms, to be returned by March 19, 1960, can be obtained from: The Director, Training Center for Experimental Aerodynamics, 72, chaussée de Waterloo, Rhode-Saint-Genèse, Belgium.

I. Nevin Palley (AF), formerly Senior Vice-President of Temco Aircraft Corp., has been elected President of the International Telephone and Telegraph Corp.'s ITT Labs. and ITT Federal Divs.

IAS *News*

News of Members

Milton B. Ames, Jr. (F), has been named Deputy Director of the Office of Advanced Research Programs in the headquarters of the NASA. Mr. Ames was formerly Assistant Director of Research for Aeronautics and Flight Mechanics.

Arnold R. Beckhardt (M) has been appointed Functional Manager of Product Support and Technical Publications at the Owego facility of IBM Federal Systems Division. Mr. Beckhardt was Senior Engineer, Manager of Flight Evaluation Supervision at the facility prior to his recent assignment.

John F. Brahtz (AF) has joined with several of his teaching colleagues at Stanford University and University of California to establish the firm John F. Brahtz Associates, Consultants-Engineers in Los Angeles. The firm is concerned with conceptual development, design and technical management for ground support installations. This organization has further combined with others to form the joint-venture firm of Bradshaw, Brahtz, Hamel & Neptune Associates, Architects-Engineers.

Maurice Nelles (M) has joined American Electronics, Inc., in the newly created post of Vice-President—Engineering. Dr. Nelles was formerly Vice-President—Research and Development and Chairman of the Corporate Product Planning Committee of Crane Co.

Harlan A. Dewell (M) has been appointed Manager of The Garrett Corporation's Los Angeles military relations office. Mr. Dewell was previously with The Garrett Corporation's AiResearch Manufacturing Div. as Project Engineer for Missile Systems.

A. P. Fioretti (A) has been appointed Manager—San Francisco territory for General Electric Company's Flight Propulsion Field Sales Operation. Prior to his new assignment, Mr. Fioretti was Manager of CJ-805 Application Engineering for General Electric's Flight Propulsion Div.

Wayland C. Griffith (M), formerly Associate Director of Research with responsibility for spacecraft and missiles, has been promoted to Assistant Director of Research for Lockheed Missiles and Space Div.

Bernhard A. Hohmann (AF), formerly Senior Staff Member and Chief Aeromechanical Section, Atlas Weapon System of the Space Technology Labs., Inc., has been appointed Project Engineer for the Atlas-Mercury Program, responsible for the STL's participation in the Mercury Program.

Richard B. Hubbard (M) has joined Roylyn Inc. as the firm's Vice-President and member of the Board of Directors. Mr. Hubbard was formerly Vice-President and Assistant to the President of the Pacific Airmotive Corp.

Col. Leigh H. Hunt, USAF (Ret.) (M), has joined Sperry Utah Engineering Laboratory, a division of Sperry Rand Corp., as a Representative. Prior to his recent retirement from the Air Force, Colonel Hunt was stationed at Hill AFB, Utah.

William R. Hutchins (M), formerly Chief, Ballistic Missiles Defense Branch of the Department of Defense Advance Research Project Agency (ARPA), has been named to the newly created post of Scientific Liaison Officer for Raytheon Co.

Jerome C. Joerger (M) has been named Manager of the Aeronautical Div. of Aerojet-General Corp. Mr. Joerger was previously in charge of the division's Systems Design Dept.

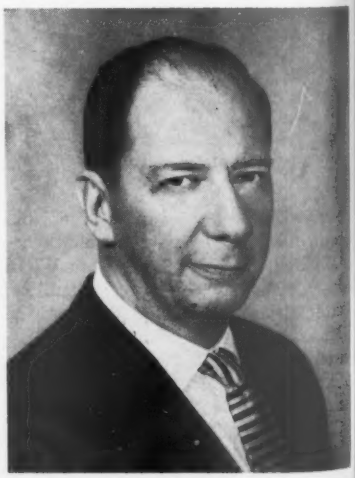
Loren F. Jones (AF) has been named Manager, Product Planning, Communications and Industrial Electronic Products Operations Div., Radio Corp. of America. Prior to his new assignment, Mr. Jones was Manager of Product Planning for RCA's Electronic Data Processing Div.

G. N. Lance (M) has been appointed to take charge of the newly formed computer group at the Atomic Energy Establishment, Winfrith Heath, Dorset, England. Until recently, Dr. Lance was director of the computation laboratory at the University of Southampton.

William C. Leone (M), formerly Manager of the Industrial Systems Div., Products Group, Hughes Aircraft Co., has been named Vice-President and General Manager of Rheem Califone Corp., a subsidiary of Rheem Manufacturing Co.

Arthur L. Lowell (AF), formerly Missile Development Test Manager for Lockheed Missiles and Space Division, has been

J. David Marks (M), who has been associated with Lehigh Valley Industries, Inc., since last September, has been elected Vice-President—Production and Engineering of the company. Prior to joining Lehigh, Mr. Marks was Manager of Engineering for G-V Controls, Inc.



Advanced hot gas systems delivered by AiResearch

FOR OUTER SPACE, ATMOSPHERIC AND UNDERWATER STEERING

AiResearch is now in production on two greatly simplified hot gas steering control systems: a reaction control system for outer space flight stabilization and a hot gas actuator control system for terrestrial steering (in the atmosphere and under water).

Both systems eliminate any need for pumps, heat exchangers, accumulators and other apparatus required in earlier control systems. And both systems utilize hot gas, operating off either the main engine or a separate fuel source.

The gas in the outer space reaction control system is fed into a set of nozzles which imparts spin to the missile to stabilize its flight through space.

In the terrestrial hot gas actuator control system the gas is fed into an on-off controlled linear actuator which moves the fins controlling the missile's attitude in the atmosphere or under water. This system also utilizes a concept developed from the AiResearch hydraulic "printed circuit." This approach eliminates complicated plumbing, thereby decreasing the weight and increasing the reliability of the system.

AiResearch is a pioneer, *leading developer and manufacturer of hot gas systems and other nonpropulsive power systems for atmospheric, underwater and outer space missions. Your inquiries are invited.*

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

named Assistant Polaris Development Manager for the Division.

Rear Adm. A. B. Metsger, USN (Ret.) (AF), has been appointed Assistant to the President of The Marquardt Corp. Prior to his recent retirement from the Navy, Admiral Metsger was a member of the Space Technology Panel, Editorial Advisory Committee of AERO/SPACE ENGINEERING.

Allan G. Norem (M), formerly Chief, Structures Section for the Aerophysics Development Corp., has joined the Technical Staff of the Advanced Research Projects Div. of the Institute of Defense Analyses, Washington, D. C.

Bernard H. Paiewonsky (A), formerly Associate Research Engineer, has been promoted to Senior Research Engineer for Aeronautical Research Associates of Princeton, Inc. Mr. Paiewonsky will be responsible for the company's studies of the motion and control of space vehicles.

August Raspet (AF), Head of the Aerophysics Dept. of Mississippi State University, was cited by the National Pilot's Association at its Wright Brothers Dinner on December 17. Dr. Raspet was honored for "his outstanding accomplishment and practical application of aircraft drag reduction and lift augmentation...."

William Solomon (M) has been appointed Chief Airframe Engineer of Bendix Products Div.—Missiles, Bendix Aviation Corp. Mr. Solomon was formerly associated with North American Aviation, Inc.

Roman M. Spangler, Jr. (M), formerly Flight Test Engineer with the Lycoming Div. of Avco Manufacturing Corp., has been named Chief of Flight Test for Vanguard Air and Marine Corp.

Richard R. Waer (M) has been promoted to Senior Scientist, Missile and Space Systems, ITT Laboratories. Mr. Waer was previously an Executive Engineer with this ITT Corp. division.

Earl A. Weilmuenster (M) has joined the technical staff of the United Research Corp. of Menlo Park as Assistant Manager of the Propellant Development Branch. Prior to his association with URC, Dr. Weilmuenster was Director of Fuels Research of the Energy Div., Olin Mathieson Chemical Corp.

Carl J. Wenzinger (AF) has been named Assistant to the President of Cook Electric Co. and assigned to the firm's Washington, D. C., office as Special Representative for Research and Development. His previous responsibilities have included those of Staff Director—AERO/SPACE ENGINEERING, and Executive Engineer—Advance Planning.

Raymond T. Zwack (M) has joined The Liquidometer Corp., Long Island City, N. Y., as Manager of Industrial Products and Systems Development. Mr. Zwack was formerly Manager of the Development Engineering Division of Solar Aircraft Co.

Necrology

Robert A. Frazer

The Institute has received news of the death of Robert A. Frazer (F) at his home in Ockham, Surrey, England, on December 10, 1959. His age was 68.

Dr. Frazer, a Fellow of the Royal Aeronautical Society, was Deputy Chief Scientific Officer of the Aerodynamics Division, National Physical Laboratory, prior to his retirement in 1954. He was a member of the Mechanics Committee of the Aeronautical Research Council.

IAS News — Corporate Member News

- **General Dynamics Corp.** has announced that through an exchange of shares, Material Service Corp. was merged into General Dynamics as the Material Service Div., effective January 1.
- **General Electric Co.** has announced the formation of a new defense systems engineering company, Apparatenindustrie Defense Electronics N. V., in The Hague, Netherlands. The function of the company, to operate as a wholly owned subsidiary of G.E., will be to participate with the NATO countries in integrating their engineering, manufacturing and management capabilities.
- **Kollsman Instrument Corp.** has announced the formation of a subsidiary in West Germany, Kollsman Luftfahrte Instrument G.m.b.H. The new company's functions will be in the development of the aircraft and guided missile programs for the German Defense Ministry and Common Market.
- **Lockheed Aircraft Corp.** has announced the establishment of a new Aerospace Technology Dept. at its Georgia Division. The department will conduct a program involving systems analysis to define the most desirable and suitable vehicle systems, project study to acquire the necessary technology for system design and proposal, and applied research in selected theoretical and experimental areas to provide a demonstrated problem-solving ability.
- **Radio Corporation of America** has signed a lease as major tenant in a new 13-story office building in Washington, D.C., which has been named the RCA building. RCA will consolidate in this building most of its Washington operations.
- **Ryan Aeronautical Co.** has acquired the Aerolab Development Co. of Pasadena, Calif., as a wholly owned subsidiary. Aerolab's function is specialization in aerophysics research.
- **Thompson Ramo Wooldridge Inc.** has acquired Radio Industries, Inc. The company will continue to operate autonomously as a subsidiary of TRW.
- **United Aircraft Corporation's** Hamilton Standard Division has announced the completion of negotiations for the purchase of a 50 per cent interest in Microtecnica, Inc., of Turin, Italy. The Italian company will undertake the manufacture of Hamilton Standard products through licensing for individual items in the jet equipment line.

IAS News — IAS Sections

Great Salt Lake Section

Physicist Sees Great Progress in Space Science

Space science will be much more active with the advent of the radio telescope, the knowledge of nuclear physics and the interest of the people in basic research; therefore, we can expect to see great progress at a faster rate than before. This was the conclusion drawn by **Dr. Robert R. Kadesch,** Assistant Professor of Physics at the University of Utah, before the December 4 meeting.

In his discussion, "**How a Physicist Looks at Space,**" Dr. Kadesch stated that the universe is not static, but that changes are constantly taking place. He also stated that the study of space science demands a universal point of view which would involve every talent there is. Even the simplest phenomenon which heretofore has been unanswered may be an important factor in solving the space problems; he cited as an example the skipping of a rock on the sandy beach as an analogy to the re-entry problem facing the space flyer coming back to earth.

Dr. Kadesch pointed out that a continual study of the solar atmosphere has enabled man to get a better understanding of space and that changes in basic philosophy have been brought about by the improvement of equipment for scientific use. For example: Some years ago it was believed that sun spots caused cyclic changes on the earth. Particularly noticeable was the effect on radio communications. More recently, it has been shown that solar flares have an extreme influence on the earth, and within about 24 hours after they are formed, radio and communications circuits are severely attacked. In fact, intercontinental communications circuits are blocked, including cable circuits. There are still some unanswered problems: for instance, the temperature on the surface of the sun is about 5,000°C, whereas away from the sun, temperatures rise to about one mil-

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lion degrees. From temperature studies, it is firmly established that the earth is in the sun's atmosphere.

It is unlikely that there is any intelligent life on the planets in this solar system, so that space travel beyond our solar atmosphere and knowledge of other systems would be more interesting and valuable. As a matter of fact, it is quite probable that there is intelligent life equivalent to that on earth in the atmosphere of other stars. Since billions of galaxies have billions of stars, the existence of billions of earth-type planets is possible. It is approximately 200 million years to some of the nearest galaxies and about 10 billion years to some of those farther away. Seeing these stars and galaxies is also a measure of the age of our universe and from the more recent studies, Dr. Kadesch asserts that the age of our universe may be at least 10 billion years.

Much of our present information has come from the famous 200-inch telescope located at Mt. Palomar in California, though, more recently, extremely interesting results have been obtained from a radio telescope located in Jodrell Bank, England. So interesting have been these data that the Naval Research Laboratory at Washington, D.C., is building a radio telescope near Sugar Grove, West Virginia. This steerable radio telescope will be of unprecedented size and more complex than any similar equipment anywhere in the world. The diameter of the antenna will be larger than the Washington monument, and the exposed area will be 7 acres. The use of this equipment in the solution of cosmology problems will be immense, partly because the band width is much wider than the optical telescope. In other words, we shall have an entirely new look at the stars, which should prove intensely interesting. Dr. Kadesch showed slides of radio telescope data of the Milky Way obtained from the English telescope.

KARL L. KOERNER, *Secretary*

W. Stanger (*left*), 1958–59 Section Chairman, applauds as D. Jamison (*center*), 1959–60 Section Vice-Chairman, introduces Dr. V. V. Holmes, Project Engineer, Advanced Design Section, Transport Aircraft, Douglas Aircraft Co., Inc., guest speaker at the Nov. 17 meeting of the Dayton-Cincinnati Section. Dr. Holmes discussed the technical and operational problems concerned with the development of supersonic transport aircraft.

Hagerstown Section

High-Speed Naval Vessels

The use of aerodynamic foils was suggested as a solution to the problem of increasing the speed of boats by **Commander Harry D. Keller** at the December dinner meeting. Speaking on "**High-Speed Naval Vessels,**" Commander Keller, USN, Technical Officer, Fluid Mechanics, Office of Naval Research, summarized the historical problems involved, including the problem of water displacement and wave formation at the discontinuity between sea and air. Aerodynamic foils to lift the hull out of the water at high speeds are normally used in one of the following types: the self regulating "V" foil, the submerged foil with mechanical "feelers" in front of the boat and the submerged foil with "depth sensing" controls.

An official U.S. Navy motion picture, "Hydrofoils," was shown to illustrate these three principles in operation.

J. C. MAYCOCK, *Secretary*

Los Angeles Section

Year-End Activities

The Wright Brothers Lecture, given by **Dr. Alexander H. Flax,** Chief Scientist, USAF, was the highlight of the December 21 dinner meeting. The lecture, "**High Temperatures in Hypersonic Flow-Physical Principles and Experimental Techniques,**" was attended by 110 members.

▶ The December 8 Specialists Meeting presented **Dr. Thomas Vrebalovich** of C.I.T.'s Jet Propulsion Laboratory. Speaking on "**A Resonance Tube in Supersonic Flow,**" Dr. Vrebalovich explained the mechanism of a temperature higher than free stream stagnation temperature, being generated in a cylinder placed in a supersonic stream with the downstream end closed. For certain conditions a given mass of air stays in the tube and is treated to a series of shock wave compressions. The discussion was based on theory and measured results and was illustrated by motion pictures.

▶ **Repertory of Early Flight Films** was the subject of the November 30 historical meeting. Before an audience of 45 members and guests, **Zeno Klinker,** writer and aviation enthusiast, gave a commentary on films covering 200 events in the development of flight. Early ballooning, the Wright brothers' work, World War I, racing, oddities, and events up to the X-15 were included.

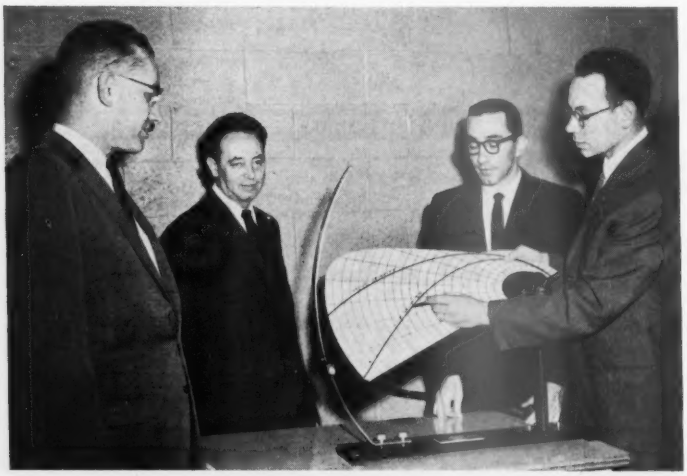
S. J. COLBY, *Secretary*

Channel Cities Subsection

Satellite Orbiting

Jack N. Nielsen (AF), a partner in Vidya Associates, was guest speaker at the December 15 dinner meeting of this subsection. Dr. Nielsen presented an

Chairman R. W. Cole (*left*) is pictured with participants in a New York Section program which took up "Selection of Lunar Probe Trajectories" on Dec. 10 at Arma Div., American Bosch Arma Corp. Also shown (*left to right*) are Morris Yachter, M. J. Molny, and P. W. Chapman, all of Arma's Space Research Staff. The group is examining a lunar trajectory analyzer developed at Arma.



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J. C. M. Frost, guest speaker at Niagara Frontier Section meeting, is shown touring Cornell Aeronautical Lab. Richard Koegler (*right*), Section Chairman, serves as guide.

authoritative discussion on satellite orbiting and the associated problems of altitude stabilization, effect of the atmosphere, spiral decay, oblateness, and in general, the dynamics of the terminal phase.

HERBERT J. SPEY, *Secretary-Treasurer*

Niagara Frontier Section

Development of the AVROCAR

J. C. M. Frost, Chief Design Engineer for VTOL Aircraft of AVRO Aircraft, Ltd., discussed the "**Development of the AVROCAR Air-Cushion - Free-Flight Vehicle**" before the November 18 meeting in the auditorium of Cornell Aeronautical Laboratory, Inc.

Mr. Frost traced the development of the family of test vehicles that led to the AVROCAR, going back to 1953 when it was discovered that a circular jet curtain would provide a suitable ground effect with reduced power requirements. He pointed out that the ground cushion effect is extremely stable in the vertical mode, listing the advantages of the circular shape. Free air vertical thrust is achieved above the ground effect region by the focussing or tilting inwards of the annular jet curtain. The mechanics of accomplishing transition to horizontal flight involves tilting the machine nose down to obtain a horizontal thrust component and accelerating horizontally until the wing action of the vehicle is capable of sustaining its weight. Mr. Frost discussed the significant characteristics of various types of air-cushion vehicles studied at AVRO.

J. M. CORD, *Secretary*

Omaha Section

Essentials of Einstein's Theory

S. M. Haley (AF), Operations Analyst, Headquarters, Strategic Air Command, discussed "**The Postulates of Einstein's Theory of Relativity,**" before the December 17 section meeting.

Mr. Haley stated that Einstein's theory of relativity is actually three theories, the special theory, the general theory and the unified theory. The special theory, the initial work, is based on two postulates briefly stated as the postulate of the relativity of all motion and the postulate of the nonvariance of the velocity of light. The special theory considers unaccelerated motion and is the source of the famous mass-energy expression $e = mc^2$. The general theory is based on two additional postulates, the principle of convariance and the principle of equivalence. The general theory considers accelerated motion and is the basis for Einstein's theory of gravitation. The third theory, the unified theory, is an extension of the previous works to include the fact that all matter consists of electrically charged particles and is to be regarded as a part of the electromagnetic field. This third theory Einstein was unable to evaluate with experimental results. As an application of these theories, Mr. Haley discussed briefly Einstein's concept of "curved space."

MICHAEL J. MCALISTER, *Secretary*

San Francisco Section

Surface Effects on Materials in Near Space

Dr. Francis J. Clauss, Research Scientist in the Metallurgy and Ceramics Department of Lockheed Missiles and Space Division, discussed "**Surface Effects on Materials in Near Space,**" before the December 17 dinner meeting. His discussion covered two aspects of the subject, the problems of temperature-control surfaces, and the wear and seizure of gear and bearing surfaces.

Dr. Clauss indicated that temperature control of spacecraft is a radiation problem, not an aerodynamic heating one, since space is essentially a vacuum. In passive (stationary) systems, the desired temperature is attained by properly tailoring the amount of radiant energy received and emitted. He pointed out that 99 per cent of radiant energy received by spacecraft lies in region of the spectrum below 4 microns (40,000 Angstroms) wavelength. This range, of course, includes the visible spectrum from 4,000 to 7,000 Å as well as the infrared above 7,000 Å. Proper regulation of energy received and emitted, he noted, depends upon the value of the alpha-over-epsilon ratio (α/ϵ), as a function of wavelength. This ratio expresses the relative ability of materials to absorb high temperature radiation from the sun and then to reradiate it at a lower temperature. Polished metals are examples of solar absorbers. These have alpha-over-epsilon ratios of about 3 or better, and "run hot." Solar reflectors, on the other hand, have low alpha-over-epsilon ratios, "run cool," and have values of α/ϵ generally less than 0.3. White oxides (Rokide) are an example of this latter category. To give some appreciation for the equilibrium temperatures attained by a spherical satellite in approximately a 200-mile orbit, Dr. Clauss said that a change from polished metal to a surface like aluminum oxide corresponded roughly to a temperature change from 95°C to −60°C respectively.

Experience with the Explorer, Vanguard, and Pioneer satellites has indicated that internal spacecraft temperatures can be kept within design tolerance. For example, the internal temperature design specification for Explorer I was −5° to +50°C. The actual temperature range experienced was +5° to +40°C, while the external surface temperature varied from −25° to +75C. In the future, however, new and additional design requirements will dictate wider variations in the alpha-over-epsilon ratio, and active (nonstationary) controls will be needed. Active controls, he said, will use mechanical devices like shutters or rotating fan blades, and expose surfaces with the right ratio, as the conditions demand.

Wear and seizure of bearings in space applications arise from the removal of absorbed surfaces normally present even on the cleanest surfaces in the atmosphere. Dr. Clauss observed that while it is difficult to lubricate moving parts conventionally in space, especially designed greases have lasted 100 hours or more in vacuum on the order of 10^{-5} or 10^{-6} mm Hg. Other means of providing lubrication in space are with thin films of solid lubricants, and the mating of widely dissimilar materials. With respect to solid lubricants, silver or gold are very good materials because of their low shear strength. Similarly, molybdenum disulfide is also good, but in addition, it has a lubricative advantage because of its lamellar type of crystal structure. Specifically, sulfur is released at the crystallographic planes during sliding action, the sulfur doing much the same job for molybdenum disulfide as absorbed water vapor does for graphite. The sulfur atoms are part of the structure, however, and are not lost in vacuum as would be the water vapor. Other good solid lubricants are nylon and teflon, but their main disadvantage is poor radiation stability. Seizure in high vacuum is minimized by use of dissimilar materials, glass, sapphire, pyroceram or carbides in contact with steel or other metal parts. The main difficulty in the use of these solids lies in their susceptibility to the high impact loads and vibration during launching.

N. R. BERGRUN, *Secretary*

Seattle Section

Fundamentals of MHD

Dr. Yusuf A. Yoler (A), Head of the Flight Sciences Laboratory of the Boeing Scientific Research Laboratories, presented "**A Review of Magnetohydrodynamics**" at the December 2 dinner meeting.

In the first of a series of meetings planned by the Seattle section to provide fundamental information in areas where the technology is changing rapidly, Dr. Yoler described and expanded on basic electro-magnecit principles. After discussing the use of MHD in generating conditions for a controlled thermonuclear reaction and the containment of the reaction, Dr. Yoler concluded with the observation that while MHD is an extremely interesting field for the physicist, practical engineering applications are as yet very limited.

JOHN K. WIMPRESS, *Secretary*

Tulsa Section

ARDC Projects

"**Air Force Research in the Aerospace Age**" was the subject of a presentation by **Col. Carlo R. Tosti, USAF**, Assistant for Command Presentations, Headquarters ARDC, at the December 14 meeting.

Beginning with a graphic representation of the history of the earth compressed into the span of one year, Colonel Tosti noted that man has been present for 15 min. and that recorded history accounts for only 60 sec. In comparison to man's compressed existence was the fact that the ever increasing rate of technical developments has increased transportation speeds from 100 to 2,000 m.p.h. within the last 50 years.

From the history of man and the advent of the airplane, Colonel Tosti proceeded with illustrations of our present technological state of the art using slides and motion pictures of several of our operational weapon systems. These included the F-100, F-105, and the B-52 aircraft, as well as the Hound Dog, Thor, and Atlas missiles, with discussion of their operational role in the present systems to future ones such as Titan, Polaris, and the air-launched ballistic missile.

Further discussion and illustrations were presented of counter weapons systems such as the early warning radar systems, the Nike Zeus anti-missile missile, the Bomark air defense missile and the MIDAS early warning satellite system.

Space research was presented by Colonel Tosti as constituting an increasing percentage of the research program of the Air Research and Development Command. Through work with the NASA, the basic military missiles are being used as boosters for scientific research programs. These research programs are designed to provide information for future space communication and weather observation and to investigate such phenomena as radiation belts and magnetic fields.

The successful accomplishment of our national effort in space has become a function of the development of the supporting sub-systems such as the propul-

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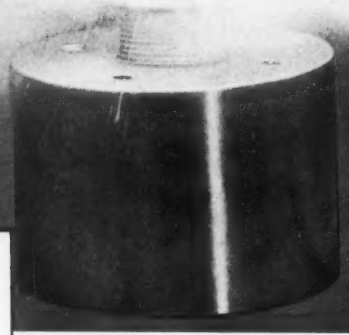

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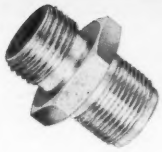

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sion systems, the electronics systems and the energy source systems. All of these must be compatible and must function properly under the extremes of space environment. Our progress with these systems was presented.

Complementary to air space and environmental investigation with missiles and satellites is the development of investigative systems capable of carrying men. Colonel Tosti discussed the evolution of our man-carrying research vehicles from the X-2 and the X-3 aircraft to the X-15, Dynasoar, and Mercury Project Satellite systems. The inherent problems associated with putting man in space require research and development to supply the necessary environment for the life cycle within a capsule. Much research has been devoted to an understanding of the capabilities of man to withstand the extremes of being accelerated into space, of being weightless while in space, and of being decelerated back into the earth's atmosphere. Continued research in the fields of biomechanics, radiobiology, and human performance is required before man can exist in space.

Colonel Tosti concluded his presentation with an explanation that a well-planned R & D program can be used to deter war and to promote science for the good of all mankind.

FRANKLIN E. PEAKE, *Secretary*

Washington Section

Geophysicist Traces Observation

"Upper Atmosphere Densities From Satellite Observations" was the subject of a discussion by **Dr. Gerhard Schilling,** Chief, Astronomy and Astrophysics Programs, NASA, before the November 17 specialists meeting.

Approaching the subject from the historical side, Dr. Schilling described satellite methods, techniques, and results, with respect to measuring density and related parameters in the upper atmosphere, beginning with Sputnik I. The problem of discrepancies in the prediction of satellite paths, as well as the determination of density and temperatures, was also discussed. Dr. Schilling pointed out that there are both latitude and seasonal effects on the height of the atmosphere.

HAROLD ANDREWS, *Secretary*

✦ ✦ ✦

Letters to the Editor *(Continued from page 7)*

Author Replies to Miele; Cites "Proved" Techniques

■ The following refers to Miele's comments on our paper "Optimum Rocket Trajectories." His interpretation of variational methods seems to be at odds with basic variational principles, and there also appears to be some confusion as to the meaning of the phrase "degrees of freedom." In the first place, it is well known that the imposition of a variational restraint restricts the solutions to a subclass of optimums, and therefore the imposition of extraneous restraints produces extraneous restrictions. In the second place, variational restraints are imposed on the integrand for only one purpose—to ensure that these restraints are observed by the solution. In the event that a condition is automatically satisfied, it must not be imposed as an additional restraint. It follows that the equations of motion (there are two in planar particle motion resulting from twice applying Newton's second law) constitute proper restraints for the case of fixed throttle setting problems, since unless these are imposed they cannot be satisfied; however, the kinematic relations (which are definitions) are automatically satisfied and clearly cannot be imposed in the form of restraints without introducing errors.

In a boundary value problem, one could impose the meaningful isoperimetric restraints—i.e.,

$$h_G = \int_1^2 V_a \sin \gamma_1 \, dt = \text{constant}$$

$$\theta = \int_1^2 \frac{V_a \cos \gamma_1 \, dt}{h_a} = \text{constant}$$

by introducing the quantities $\lambda_m V_a \sin \gamma_1$ and $\lambda_n[(V_a \cos \gamma_1)/h_a]$ into the variational integrand with λ_m and λ_n as constants; however, this procedure limits the solution range to only those paths passing through the point h_G, θ at time t, and therefore is meaningless on an initial value basis where h_G and θ at t are to be determined optimally.

In a dynamic problem the number of defining equations of motion is equal to the number of physical degrees of freedom (not to be confused with mathematical degrees of freedom), and the number of Euler equations required to define particle motion cannot exceed the number of physical degrees of freedom. Thus Miele is incorrect in writing his Eqs. (5), (6), and (7) since, for the assumptions he has made, his Eq. (6) has all terms zero, and h is certainly not a degree of freedom if V and γ are freedoms since, evidently

$$h = \int V \sin \gamma$$

by definition, so that h is defined uniquely if V and γ are specified as functions of time.

Thus a casual application of variational techniques to physical problems often results in error, and the use of superfluous restraints is just such a casual application which leads to a set of equations insolvable even on an initial value basis. Faced with such a set, the procedure is either to set to zero the offending Lagrange multipliers (which amounts to correcting the erroneous physical assumptions) or to set to zero some physical quantities which are not zero. This latter procedure destroys the problem physically and introduces the concept of "subarcs" which do not exist in the real system.

A perfect example of this physically incorrect type of thinking is an attempt to define airplane climb performance while ignoring induced drag or while assuming that lift equals weight during dynamic maneuvers. Either of these assumptions amounts to ignoring changes in flight path attitude and is entirely equivalent to discarding the equation of motion normal to the flight path—i.e., $\dot{\gamma}$ is set equal to zero even though it clearly cannot have this value. Since Miele's "pilot example" commits this error, we feel that he has fallen prey to this physically incorrect mode of thinking.

Miele's Approach B, which he calls the Dommasch-Barron approach, is *definitely not our approach.* In the first place, if the stipulation is made that $\dot{\gamma}$ cannot exist, then it is not physically meaningful to write Eq. (12), since both terms in this equation and their derivatives are identically zero (by definition). In the second place, since $\dot{\gamma}$ cannot exist, there is only one equation of motion and γ can be eliminated entirely from the problem. Thus, although we consider such an application preposterous, since any real climb involves nonzero values of $\dot{\gamma}$, the proper approach would be as follows: since only one equation of motion exists, it yields the holonomic condition that

$$\sin \gamma \equiv E - \dot{V}/g$$

which serves to eliminate γ from the problem. Hence

$$G = V(E - \dot{V}/g) \text{ [not Miele's Eq. (13)]}$$

and the only Euler relation is

$$-(\dot{V}/g) - (E - \dot{V}/g) - V(\partial E/\partial V) = 0$$

(note the absence of any multiplier)

where

$$\frac{\partial E}{\partial V} = \frac{1}{mg}\left[\frac{\partial F}{\partial V} + \frac{\partial F}{\partial h}\cdot\frac{\partial h}{\partial V} - \frac{\partial D}{\partial V} - \frac{\partial D}{\partial h}\cdot\frac{\partial h}{\partial V}\right] - \frac{\dot{m}(F-D)}{gm^2}$$

where F = thrust. Thus Miele's interpretation of our thinking is incorrect, as well as his physical reasoning.

Finally we should like to advise that there exist no sufficient conditions for the problems discussed and that "the proof of the pudding is, therefore, ultimately in the eating." We have available ample numerical and experimental proof that our techniques are valid, and it is a matter of documented history that these techniques provided the first accurate prediction of optimum zoom climbs in 1955.

Conclusions

(1) The variational methods suggested by Miele seem to be physically incorrect, and therefore are incapable of producing valid solutions to real trajectory problems.

(2) The techniques suggested in our paper are tried and proved, and have been experimentally verified.

(3) Since it is our opinion that the techniques suggested by Miele are incorrect and mathematically and physically misleading, we should like to suggest that he subject his methodology to the same acid tests as have we. Namely, he should try to achieve solutions on the digital computer to real problems using his proposed methods. We are certain that such tests will be revealing to both him and his associates, and should serve to eliminate future misunderstanding.

Daniel O. Dommasch
President, DODCO, Inc.
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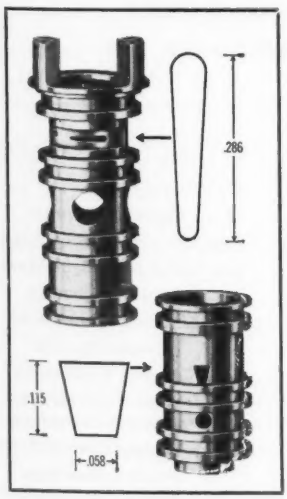

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EDITORIAL

The Aerospace Technology Panels

One of the more important tasks before the Officers and Council at the recent January Meeting was the appointment of members for the new Committees of the Council. Careful consideration was given to the selection of the most highly qualified people to advise the Council on matters relating to Long-Range Policy, National Meetings Policy, and Publications Policy. The membership of these three committees will be published shortly. No changes were made in the rosters of the other standing committees—i.e., Education and Membership.

A great deal of discussion centered about the functions and make-up of the Aero/Space Technology Panels, which, it will be remembered, occupied the center area of the Institute's Operational Plan chart published in AERO/SPACE ENGINEERING (Editorial) in August, 1959, and which was also a part of the ballot by which the membership approved the Plan.

The next step in the program is to select groups of five to ten men in our several fields of interest who are highly qualified, on grounds of both long experience and current activity, to help IAS program planners select subjects and speakers. Such Panels of experts may never meet as a group, but it is expected that they will establish some sort of intercommunication where group opinion on any subject seems desirable.

As was pointed out in the original discussions, the function of these Panels is *advisory only*. This was reaffirmed, and restated as a basic concept. These groups will have no responsibility whatever for the planning or the operation of any Institute meeting or technical program. Such things are to be handled (as at present) by the National, Regional, or Section program planning committees. The experts on the Panels, however, individually or collectively, will be available (by mail, telephone, or personal contact) to assist and advise program planners as to currently interesting technical topics and the people most qualified to talk on such topics.

This differs from the system which has been followed by certain of the older societies for many years—i.e., the so-called Professional Committee plan, under which the several professional groups actually plan for, implement, and operate special meetings in their areas of interest. Here we want our Sections and our Regions to continue to be autonomous in their own activities—planning their meetings to meet the needs of their local and regional membership. In doing so, however, we want them to have available the advice of the best people in the country, in any particular discipline or branch of science or engineering.

As with any program of this size, optimum operation will not come about overnight. This Plan has been in limited operation for some time (in fact, on a National basis, for many years). One of the first requisites will be the complete manning of all Panels and the publication of Panel Rosters to all Regional and Section Officers. This will be done in the very near future. Meanwhile, the Secretary will be glad to put anyone engaged in planning a meeting in touch with any of our list of experts in any of our related areas.

S.P.J.

Estimates of the gross power requirements are summarized and extended to include estimates of the payload-range capability. These data are then utilized to illustrate the "working rate" capability of "off-the-road" air-cushion vehicles compared with more conventional transportation media.

Potential of the Air-Cushion Vehicle

Roy P. Jackson, AFIAS, and Murray F. Southcote, AIAS

Aeronutronic
A Division of Ford Motor Company

THE BASIC objective of this study is to illustrate the potential of the air-cushion vehicle as a means of transportation.

Two distinctly different air-cushion techniques may be utilized in the design of a transport system. One is to utilize an air cushion as a means of supporting a vehicle over prepared surfaces, such as a rail or road system with very close clearances. In this role, the air-cushion acts as a low-friction lubricant and offers the potential of a safe, efficient, high-speed means of transportation. This technique is often referred to as the levapad or air-bearing principle.

Considerable pioneering work has been performed on this technique by Dr. A. A. Kucher, Vice-President, Engineering Research, Ford Motor Company. Fig. 1 illustrates the application of this "on-the-road" technique to an intercity rapid transit system.

The other basic concept of the air-cushion principle is to provide a means of transportation over all types of unprepared terrain. In this concept, a cushion of low-pressure air supports the vehicle above the ground. The annular jet and plenum chamber typify the current approach to this technique. This method offers the potential of operation over all forms of unprepared terrain such as water, snow, mud, ice, etc., if sufficient clearance is provided. Fig. 2 illustrates this concept as a means of "off-the-road" transportation.

Time does not permit a thorough discussion of both these techniques. This paper considers the potential of air-cushion vehicles as a means of "off-the-road" transportation and compares some of the salient features of these vehicles with other existing means of transportation.

This article is a revised and condensed version of the authors' paper presented before the Ground Effect Vehicles Session, IAS 28th Annual Meeting, N.Y., Jan. 25–27, 1960. (The complete paper is available as IAS Paper No. 60-15.)

This work has been conducted under contract for the Transportation Research Command (TRECOM) of the U.S. Army Transportation Corps, Fort Eustis, Va. Their permission for the presentation of this paper is gratefully acknowledged.

Hovering Power Requirements

Air-cushion vehicles are supported above the ground by a bubble or cushion of low-pressure air. This cushion of air permits the vehicle to travel over all types of unprepared terrain if sufficient clearance over obstacles is provided.

Reference Hovering Power

In any quantitative discussion, it is first necessary to settle on a frame of reference. There are, in the case of air-cushion vehicles, many logical definitions to utilize in establishing a frame of reference. After examination of the alternatives, the frame of reference suggested by H. Chaplin[1] appears to be the most useful. The basic consideration is, given a planform area S and a lift requirement W, what is the power required? By simple momentum considerations, the lift that can be generated is equal to the mass flow through the planform area S, times the increase in velocity imparted to this mass flow. The power required is given by the rate of change of kinetic energy. This can be expressed as one half the mass flow times the square of the velocity imparted to the air. Solving these two expressions for the velocity results in the expression for the power required.

$$P_{i\infty} = [W/(2\sqrt{\rho})]\sqrt{W/S}$$

The concept, then, is to define the power required for the annular jet and the plenum chamber in terms of this reference power, and to further show how the power required varies as a function of the height of the vehicle above the ground.

Annular Jet Theory

Annular jet-type air-cushion vehicles confine the bubble of low-pressure air beneath the machine by means of a jet of air exhausted around the periphery of

Mr. Jackson, General Operations Manager, Tactical Weapon Systems Operation of Aeronutronic, has been engaged in weapon systems research, development, and manufacture for 17 years. Prior to joining Aeronutronic, he was Manager of Systems Engineering on the Titan ICBM at Martin, Chief Engineer at Northrop, and Project Technical Engineer at North American where he worked on many programs, including the F-86 and F-100. He began his professional career at Ames Aeronautical Laboratory and was graduated from Stanford University.

Mr. Southcote is Manager of the Air-Cushion Feasibility Investigation at the Tactical Weapon Systems Operation of Aeronutronic. Among his specific assignments, during 9 years' experience in the design, development, and flight test of aircraft and missiles, have been project aerodynamic responsibility on the Hawk Missile, design work on application of low-drag boundary-layer control, and duties in the preliminary design phase of new weapon systems. A graduate of the University of Toronto, he began his professional career at Northrop.

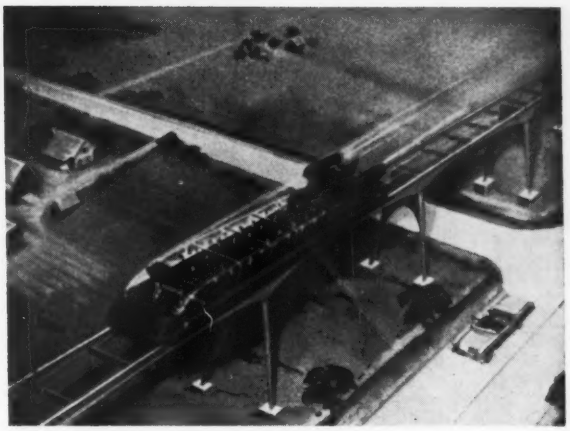

Fig. 1.

the vehicle. The pressure level of this cushion of air is dependent upon the force balance between the pressure forces in the air cushion and the centrifugal forces associated with the resulting outward deflection of the annular jet.

The basic theoretical considerations determining the power required for the annular jet have been defined in reference 1. This basic momentum theory defined the theoretical hovering power requirements for annular jets with circular planforms. As detailed in references 2 and 3, this basic theory can be extended to account for any planform shape. The experimental data of reference 4 indicate the validity of this theory.

The theoretical hovering power requirement for the annular jet may be expressed as

Fig. 2.

$$P_T = \left[\frac{\sqrt{1 + \frac{S_J}{S_b}} \left(\sqrt{\frac{1}{S_J/S_b}} + \sqrt{\frac{S_J}{S_b}} \cdot \frac{1 - \sin\theta}{[h/(S/l)]\sqrt{1 + (S_J/S_b)}} \right)}{\left(\cos\theta + \frac{1 - \sin\theta}{[h/(S/l)]\sqrt{1 + (S_J/S_b)}} \right)^{3/2}} \right] \frac{W}{2\sqrt{\rho}} \sqrt{\frac{W}{S}} \quad \frac{\text{ft.lbs.}}{\text{sec.}}$$

It is apparent that the required power is given by the function in the brackets, times the power required for the reference lifting system operating out of ground effect. We have defined the term in the brackets G as the "theoretical hovering ground effect power factor." G represents the reduction in power requirements that can be achieved by operating in the presence of the ground.

Plenum Chamber Theory

The principle of operation of the plenum chamber air-cushion vehicle is to maintain a cushion of low-pressure air within the plenum by means of an actuator of fan system. This cushion of air, which supports the vehicle above the ground, will leak out around the periphery of the vehicle. An equilibrium height will be

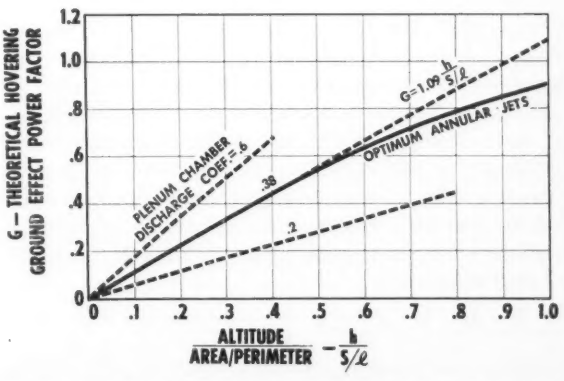

Fig. 3. Theoretical hovering ground effect power factor, all planforms.

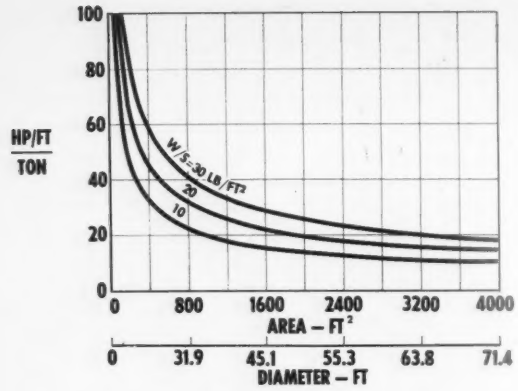

Fig. 4. Hovering power, circular planform.

established when the flow in through the actuator is equal to the flow out around the periphery.

The analysis of the power requirements of a plenum chamber uses the same momentum principles used in the annular jet theory. The power required is given by the volume flow times the pressure rise.

$$P_T = \Delta p S_z V_z \quad \text{ft.lbs./sec.}$$

If low velocities are maintained in the plenum chamber, the total work done by the fan or actuator can be supplied to the plenum chamber in the form of static pressure. The lift will then be $W = \Delta p S$. As this cushion of air escapes around the periphery of the vehicle, the flow will accelerate and cause the so-called *vena contracta*, thus reducing the leakage area. The effective exit area may be expressed as $S_z = lhC$, where C is the discharge coefficient.

The velocity of the air as it escapes is given by $V_z = \sqrt{2\Delta p/\rho}$. By substitution in the power expression for Δp, S_z, and V_z, the theoretical hovering power required is given by

$$P_T = \{2.83C[h/(S/l)]\}\ [W/(2\sqrt{\rho})]\ \sqrt{W/S}$$

Thus, in a manner similar to the annular jet, the power required for the plenum chamber may be expressed as a theoretical hovering ground effect power factor G, times the power required for the reference lifting system $P_{1\infty}$.

The variation of G with height parameter is given in Fig. 3, where the plenum chamber is shown for various values of the discharge coefficient C. Although two-dimensional theory indicates that $C = 0.6$, it may be possible to reduce this coefficient. The introduction of some type of aerodynamic spoiler arrangement may efficiently reduce the effective exit area considerably. To date, the plenum chamber concept has not received the same attention as the annular jet. It is therefore difficult to generalize as to the relative merits of the two concepts.

Ground Effect Power Factor

In the two preceding sections, relations were defined for determining hovering power required for annular jet and plenum chamber air-cushion vehicles. These theories were expressed in terms of the ground effect power factor G, the height parameter $h/(S/l)$, and the reference hovering power $P_{1\infty}$.

The advantage of the use of G is that it illustrates the effect of the close proximity of the ground on the power required to hover. Without the benefit of the ground effect phenomenon, an "ideal" lifting system requires $P_{1\infty}$ to hover. The ground effect phenomenon permits hovering with less power than $P_{1\infty}$, and G shows the magnitude of the reduction.

Fig. 3 demonstrates, quite simply, that to operate at power requirements substantially lower than those required for flying, the air-cushion vehicle must operate at low values of $h/(S/l)$.

It can be seen that the variation in G, for the annular jet, can be approximated by a straight line over a wide range of the height parameter. This straight line also represents G for plenum chambers if C can be reduced by means of some type of aerodynamic spoiler to a value of 0.38.

Since G is linear with the height parameter, the determination of P_T is simplified by the use of the approximation

$$P_T = 1.09\ [h/(S/l)]\ [W/(2\sqrt{\rho})]\ \sqrt{W/S}$$

Shaft Power Required

The above theoretical hovering power requirement is only part of the story in that in the design of any system such as this—in which an inlet, fan, or actuator system and ducting are necessary parts—the relative efficiency of these components must be given careful consideration. In order to present some pertinent design information in subsequent sections, a 10 per cent internal ducting power loss was assumed. A loss of 14 per cent was assumed in the conversion of shaft horsepower into air horsepower at the fan or actuator. To account for unknown inaccuracies in the theory, such as viscosity effects, a further loss of 10 per cent was assumed. The net result, in subsequent sections, of these assumptions of efficiency is that installed power required is 1.4 times the theoretical horsepower required (efficiency = 70 per cent). It is believed that this power ratio can be achieved in a well-designed system.

Installed Hovering Power

Using the foregoing power relations and the 70 per cent efficiency factor, the power required per foot of altitude for an annular jet of circular planform is

$$\text{hp./ft.} = (0.1045/\sqrt{\sigma})(W/\sqrt{S})\ \sqrt{W/S}$$

where $\sigma = \rho/\rho_0$, air density ratio. The horsepower per foot altitude per ton gross weight is given by

$$\text{(hp./ft.)/ton} = (209/\sqrt{\sigma})(1/\sqrt{S})\ \sqrt{W/S}$$

Fig. 4 shows this quantity for a range of W/S estimated to be typical of air-cushion vehicles. As illustrated, the horsepower per foot per ton of gross weight is presented as a function of the planform area, for

constant values of planform loading. The large reduction in power required as the size increases is evident. The reason is apparent from a consideration of the simple momentum theory. The lift that is generated depends on the area which increases with the square of the diameter. The perimeter which determines the power required varies directly with the diameter. For example, if the diameter is doubled, the area and therefore the lift increases by a factor of 4, whereas the perimeter and therefore the power required increases by only a factor of 2. As a result, the horsepower per unit lift is reduced by a factor of 2. This basic and simple relationship is illustrated in Fig. 4. The thing to note is the inherent increase in efficiency of air-cushion vehicles as the size increases (assuming that height remains constant).

Fig. 4 illustrates the significant reduction in hovering power requirements as the vehicle size increases and, further, the advantages of low planform loading in reducing the hovering power.

Power Required to Overcome Drag

In the previous considerations of the power required in hovering, there was available a firm theoretical basis for the estimations. In addition, there were available some experimental data which prove the validity of the theory. However, in considering the power required to overcome the drag of the vehicle in forward motion, we find that not only is the problem more complex but there is very little directly applicable experimental data. Nevertheless, it is believed that the drag estimates presented here are representative of what can be achieved by a thorough understanding of the physical principles involved and by careful attention paid to the design parameters which influence the drag of the vehicle. The basis for this position is the wealth of data, both theoretical and experimental, defining the drag characteristics of both aircraft and automobiles.

Consider the so-called profile drag of such vehicles. We know that if the vehicle is streamlined (that is to say, of high fineness ratio), the profile drag coefficient can be reduced to the point where it is composed primarily of the skin friction drag which is of the order of 0.005, based on the planform area S. However, it must be realized that, in order to achieve such a low drag, the planform shape will be very poor from the lifting point of view, and the power requirements for lift will be extremely high.

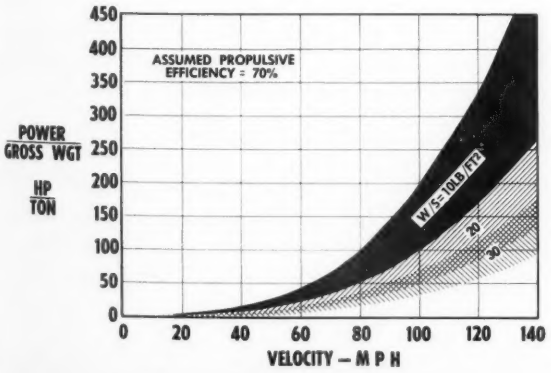

Fig. 5. Power required to overcome drag.

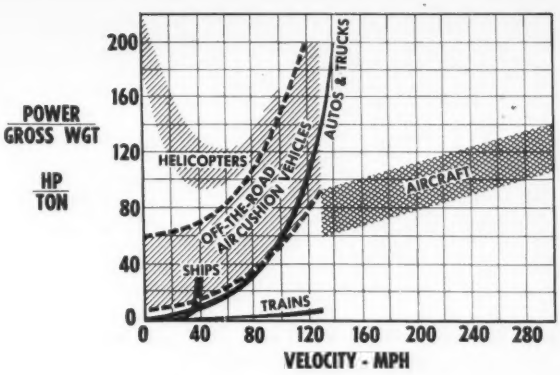

Fig. 6. Summary of gross power requirements.

At the other end of the spectrum we can minimize the power required for lift by utilizing a circular planform, and, as a consequence, the profile drag will be high. This profile drag will be composed primarily of pressure drag rather than friction drag and can get extremely high depending upon both the frontal area and the base area of the vehicle.

To permit an evaluation of the air-cushion vehicle as a means of off-the-road transportation, it is necessary to present some drag data that could be considered typical. Fig. 5 illustrates the horsepower per ton of gross weight to provide some "ball park" estimates of power required to overcome drag. These power requirements are shown as a function of speed and planform loading. A spread in profile drag coefficients from 0.05 to 0.1 based on planform area is considered to represent a typical variation. It is worthy of note that these drag coefficients, by aviation standards, are relatively high. They represent drag coefficients five to ten times larger than profile drag coefficients of modern conventional aircraft. These power requirements were estimated conservatively to provide for unknowns which may arise because of the absence of specific data. Further, in the presentation of these power requirements, it was assumed that a propulsive efficiency of 70 per cent could be achieved.

Any discussion of power required in forward motion must consider the momentum drag. The momentum drag can easily double the drag estimates presented if the air brought on board the vehicle is not handled in an efficient manner.

The modern turbojet aircraft demonstrates how the kinetic energy of the air, relative to the vehicle, can be used to create a "ram pressure" rise in static pressure. Similarly, the air-cushion vehicle must utilize such techniques if the vehicle is to be efficient at forward speeds above 20 m.p.h. or so. By means of an efficient diffuser, the recovery of ram pressure may be utilized to reaccelerate the air back to free-stream velocity on discharge.

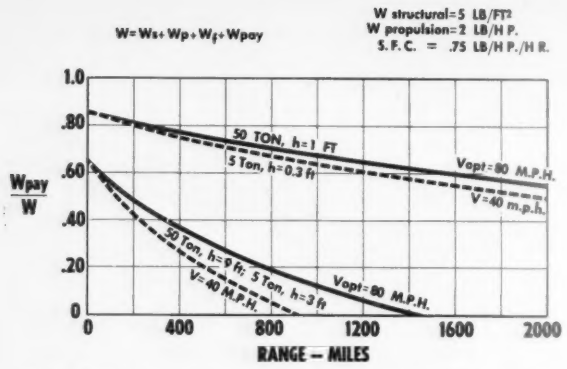

Fig. 7. Effect of cruise velocity, air-cushion vehicle payload-range.

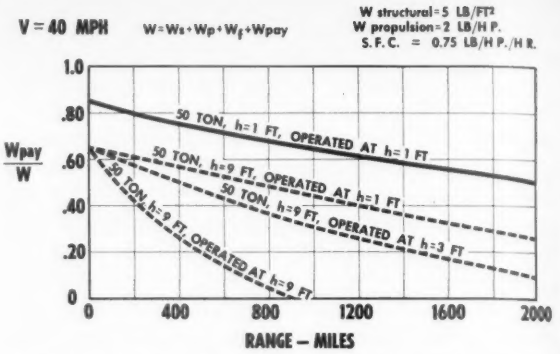

Fig. 8. Effect of operating height, air-cushion vehicle payload-range.

An assumption as to the efficiency of this diffusion and acceleration must first be made. For simplicity, it has been assumed that it can be accomplished with 100 per cent efficiency. Admittedly this is optimistic, but it is well established that such a process can be accomplished with an efficiency of 90 per cent or better at the design point.

Summary of Gross Power Requirements

The gross power requirements of typical off-the-road air-cushion vehicles are compared with several conventional transport media in Fig. 6. These data illustrate typical horsepower requirements per ton of gross vehicle weight as a function of velocity.

In order to illustrate typical characteristics for off-the-road air-cushion vehicles, it was necessary to define a band of typical height requirements. It was considered that heights from approximately 1 to 10 ft. would provide a significant and realistic off-the-road capability. In addition, it is necessary to consider a band of operational sizes because, as noted earlier in Fig. 4, size plays an important part in the determination of the lift power requirements.

For purposes of illustration, it was decided that a 50-ton vehicle designed to operate at 1 ft. and at 9 ft. would present a typical set of conditions. These data are also representative of a 5-ton vehicle designed to operate at 0.3 and at 3 ft., respectively. The data were calculated on the basis of a circular planform with a drag coefficient of 0.05 based on the planform area.

The data in Fig. 6 for ships, trains, autos and trucks, and aircraft were obtained from reference 6. The helicopter data illustrate the variation of gross power required with forward velocity, typical of modern helicopters. The data of reference 7 indicate that these power requirements are typical for the modern turbine-powered helicopter.

Air-Cushion Vehicle Payload-Range

The foregoing summary of gross power requirements, although interesting, does not provide a measure of the true effectiveness of these various transportation systems because it does not consider the payload-range characteristics of the various systems. In order to provide some quantitative estimates of the payload-range characteristics of the off-the-road air-cushion vehicle, it is necessary to estimate typical values for the structural and propulsion system weights and the fuel consumption.

Because of the absence of a background of structural design criteria for air-cushion vehicles, it is difficult to present a refined estimate of the structural weights. However, it is believed that, by utilizing the efficient structural techniques developed in the aviation industry, structural weights of approximately 5 lbs. per sq.ft. of planform area can be achieved. Undoubtedly, there will be instances where particular design criteria will dictate structural weights, both greater than and less than this value.

In estimating the propulsion system weight, the use of the modern shaft turbine engine was considered. Great progress has been made with this power plant in the last few years, and a weight of approximately 0.5 lbs. per hp. is available today. Similarly, a specific fuel consumption of about 0.5 lbs. per hp.-hr. is currently available. For this analysis, it was assumed that the installed propulsion system for an air-cushion vehicle could be achieved for 2 lbs. per hp. Similarly, it was estimated that the installed specific fuel consumption would be 0.75 lbs. per hp.-hr. With these assumptions, the gross weight may be expressed as

$$W = W_{\text{structure}} + W_{\text{propulsion}} + W_{\text{fuel}} + W_{\text{payload}}$$

Payload-Range

During cruise at constant velocity and height, the gross weight will decrease because of the consumption of fuel. As a result, the expression for the range is given by

$$R = \frac{V}{\text{s.f.c.}}\left(\frac{\text{W}}{\text{hp.}_I}\right)_1 \frac{2/3}{Z}\left[\frac{1}{2}\ln\frac{Z^2 - Z + 1}{Z^2 - Z\sqrt{x} + x}\left(\frac{Z+\sqrt{x}}{Z+1}\right)^2 + \sqrt{3}\left(\tan^{-1}\frac{2-Z}{\sqrt{3}\,Z} - \tan^{-1}\frac{2\sqrt{x}-Z}{\sqrt{3}\,Z}\right)\right]$$

where

$x = W_2/W_1$
$Z = (\text{hp.}_{\text{drag}}/\text{hp.}_{\text{lift}})_1^{1/3}$
W_1 = weight at start of cruise
W_2 = weight at end of cruise

In order to maximize the payload capability for any given range, it is necessary to design the vehicle with the optimum planform loading W/S and operate the vehicle at the most efficient speed. In order to simplify the analysis, the optimization process was conducted only for a circular planform with a drag coefficient (based on the planform area) of 0.05. This was considered justifiable in view of the significant increases in planform fineness ratio that can be achieved with relatively minor increases in the lift power requirements as compared with the major effects of planform loading.[2] Fig. 7 presents the results of such a payload-range analysis.

The upper curve on Fig. 7 represents the payload-range of a 50-ton vehicle designed for 1 ft. height operating at its optimum cruise velocity of approximately 80 m.p.h. These data are also representative of the payload-range characteristics of a 5-ton vehicle operating at approximately 0.3 ft.

It is quite possible that this optimum cruise velocity of 80 m.p.h. may be extremely difficult to achieve in practice. Consider the control problems associated with this 50-ton vehicle traveling at 80 m.p.h. 1 ft. over unimproved terrain. Obstacles that would require more than 1-ft. clearance must be circumvented, and, in order to accomplish this, an extremely powerful and responsive control system would be required. Even if this were available, it is doubtful if the reactions of the driver would be quick enough, particularly in connection with overland operation. It is conceivable that this speed could be maintained on an inland water system—for example, the Mississippi River—but, in the authors' opinion, it is highly unlikely in most overland operations.

It is difficult to specify a typical speed limit. Undoubtedly, the limit would depend to a large extent on the drivers' ability and on the effectiveness of the control system. However, to illustrate the effects of the imposition of a speed limit, the payload-range data for the 50-ton vehicle at 1 ft. (5-ton at approximately 0.3 ft.) when designed to a speed limit of 40 m.p.h. are presented.

To represent the payload-range characteristics of air-cushion vehicles designed for higher altitude operation, the 50-ton vehicle operating at 9 ft. and operating at its optimum cruise velocity of approximately 80 m.p.h., is also presented. By coincidence, the optimum cruise velocity for this vehicle is the same as for the 50-ton vehicle at 1 ft. These data are also representative of the payload-range characteristics of a 5-ton vehicle operating at 3 ft.

Similarly, data are presented which illustrate the resultant payload-range characteristics if a speed limit of 40 m.p.h. is imposed. In summary, Fig. 7 presents payload-range data considered typical of air-cushion vehicles designed for off-the-road operation.

Effect of Operating Height

As noted on Fig. 7, there is a tremendous variation of the payload-range capability with operating height. Consider, for example, the 50-ton vehicle designed to operate at 9 ft. In actual operation it would be wasteful to operate this machine at its maximum height of 9 ft. if the terrain did not call for it. Fig. 8 is presented to illustrate the significant increase in the payload-range characteristics of this vehicle if it is operated at 3 ft. and at 1 ft.

Effect of Structural Weight

As noted earlier in the construction of the data of Fig. 7, the weight of the structure was based on an intuitive feeling for what can be accomplished if efficient lightweight aviation-type structure is employed. To emphasize the importance of this aspect of the design of air-cushion vehicles, Fig. 9 presents payload-range data with a structural weight of 10 lbs. per sq.ft. As illustrated, there is a significant reduction in the payload-range characteristics if the structural weight is increased.

Payload Power Requirements

Fig. 10 presents a summary of the payload power requirements of vehicles capable of operating over unprepared terrain. The horsepower per ton of payload is shown as a function of range. These data are more

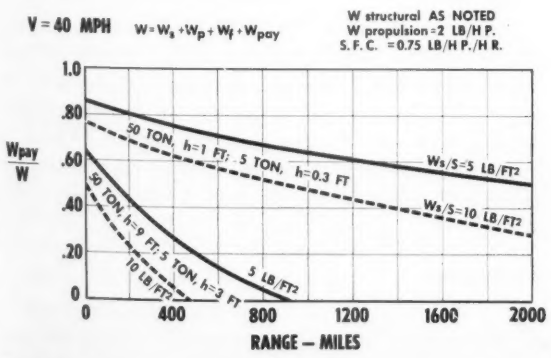

Fig. 9. Effect of structural weight, air-cushion vehicle payload-range.

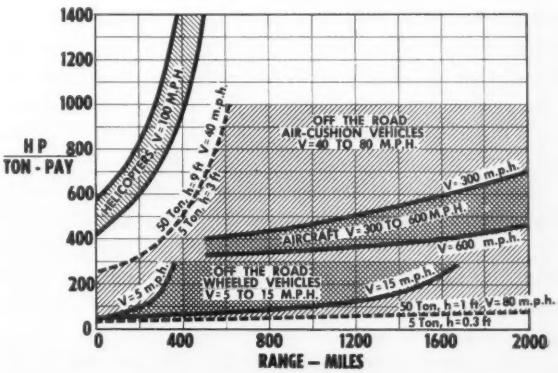

Fig. 10. Summary payload power requirements.

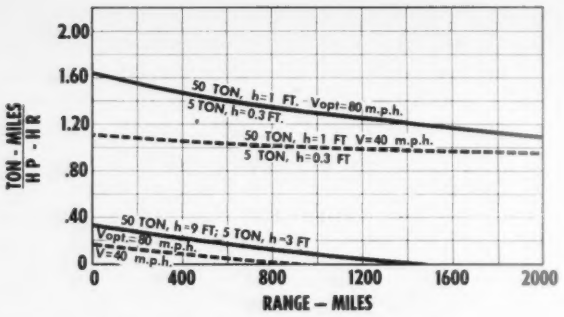

Fig. 11. Working rates, air-cushion vehicles.

meaningful than the gross power summary presented in Fig. 6 in that the payload-range characteristics of the various transportation systems are considered.

Air-Cushion Vehicles

The off-the-road air-cushion vehicles were taken from the data used to construct the payload-range information presented in Fig. 7. The upper bound is the 50-ton vehicle operating at 9 ft. at 40 m.p.h. (5-ton vehicle at 3 ft. at 40 m.p.h.). The lower bound is the 50-ton vehicle designed and operated for 1 ft. at its optimum cruise velocity of 80 m.p.h. (5-ton at 0.3 ft. at 80 m.p.h.).

As noted earlier, there is a tremendous variation in the characteristics of off-the-road air-cushion vehicles.

Wheeled Vehicles

The operational characteristics of wheeled vehicles when utilized in off-the-road operation were taken from reference 8 and 9. In general, the wheeled vehicle when used on-the-road represents an efficient means of transportation. The payload-range characteristics are good in that the payload plus fuel can be approximately half the gross weight. The power requirements are low, and, as a result, the fuel requirements are low. However, when this wheeled vehicle is utilized as a means of off-the-road transport, some serious deficiencies are immediately obvious:

(1) The vehicles are extremely limited in their ability to traverse the wide varieties of terrain that are encountered in off-the-road operation.

(2) Even in those instances where operation is possible, the characteristics are still relatively poor because (a) the speed is reduced to just a few miles per hour, and (b) as a result of the severe loads imposed on the suspension system, the payload plus fuel capacity is reduced to approximately 30 per cent of the gross weight.

As in the case of air-cushion vehicles, there is a wide variation in the payload power requirements that may be encountered. The upper bound, as illustrated in Fig. 10, is considered to represent typical terrain conditions which require the use of maximum power, and the speed is limited to low values, like 5 m.p.h.

The lower bound represents conditions where the terrain will permit an average speed of approximately 15 m.p.h. with a power requirement approximately 1/3 of the installed horsepower.

Admittedly, the bounds described are somewhat arbitrary; however, it is felt that they are representative of the extremes, both good and bad, that will be encountered in the operation of wheeled vehicles off-the-road.

The air-cushion and wheeled vehicles are two means of off-the-road transportation. The other alternative is to cast off terrain restrictions completely and utilize the flying machine.

Helicopter

The helicopter represents a transportation technique capable of off-the-road transport. Its ability to take off, hover, and land vertically is a unique feature and sometimes a most priceless commodity. Unfortunately this capability requires considerable power and mechanical complexities.

The payload power requirements illustrated in Fig. 10 are representative of the characteristics of the modern turbine-powered helicopter. Examination of reference 7 indicates that the total payload plus fuel weight is of the order of 40 per cent of the gross weight. Utilizing the power requirements illustrated in Fig. 6, the optimum payload-range characteristics are achieved with a cruise speed of approximately 100 m.p.h.

The fuel consumed was calculated by taking the gross power from Fig. 6 at 100 m.p.h. and using a specific fuel consumption of 0.75 lbs. per hp.-hr. With the payload-range characteristics defined in this manner, the installed horsepower per ton of payload as a function of range is found.

Aircraft

In order to summarize the payload power requirements of modern aircraft, the modern propeller-driven reciprocating-engine-powered aircraft and the modern turbojet-powered aircraft were considered.

The data of reference 7 indicate that the payload plus fuel of a modern propeller-driven aircraft represents approximately 40 per cent of the gross weight. Assuming an s.f.c. of 0.5 lbs. per hp.-hr., a cruise speed of 300 m.p.h., and an L/D of 12, the fuel requirements are defined by means of the familiar Breguet range equation. These data were used to present the upper bound shown in Fig. 10.

Similarly, the lower bound is representative of what can be achieved of the modern turbojet-powered aircraft. Reference 7 indicates that the fuel plus payload will equal approximately 55 per cent of the gross weight. With an s.f.c. of 1 lb. per hour per pound of thrust, a velocity of 600 m.p.h., and an L/D of 20, the fuel required is obtained by means of the Breguet range equation.

Working Rates

The preceding summary of payload power requirements, although meaningful, does not reflect the importance of speed of the various systems. In the final

analysis of an evaluation of the relative merits of the various means of transportation, direct and indirect costs are the most meaningful criteria. However, to provide a thorough cost analysis of the various modes of off-the-road transportation is an extremely complicated problem and far beyond the scope of this paper.

Still, it is believed, a good indication of the relative merits can be obtained by considering what is referred to as the "working rates." In most cost analyses, the installed power of the transportation system is a primary influence in determining the cost of operation. For example, it is a primary factor in the operational costs such as fuel and maintenance. Further, the installed power has a predominant influence on the procurement cost of the vehicle.

In most cost analyses, payload (tonnage), distance (miles), power required (horsepower), and time (hours) are primary influences in determining cost of transportation. Therefore, the working rate—i.e., the ability to move a ton of cargo a given number of miles, in a given period of time, with a given amount of horsepower—is an important consideration. Such a working rate may be defined from the data presented earlier by dividing the cruise speeds by the horsepower per ton of payload. This parameter represents the ton-miles delivered per horsepower-hour and as such is representative of the efficiency of the transport system.

Air-Cushion Vehicles

Fig. 11 presents working rate capabilities believed to be typical of off-the-road air-cushion vehicles and is constructed using the payload-range data of Fig. 7 and the installed power used in the calculations for the payload-range data of Fig. 7.

Although the speed limit of 40 m.p.h. that was imposed did not penalize the payload-range characteristics too seriously (Fig. 7), the data in Fig. 11 indicate much more clearly the deleterious effects on the working rate capability of such a speed limitation.

Summary of Working Rates

Fig. 12 presents a summary of the working rates of vehicles capable of operating over unprepared terrain. The working rate is shown as a function of range. These data are more meaningful than the payload power summary presented in Fig. 10 in that the velocity of the various transportation systems is considered. These data were constructed from Fig. 10 by dividing the cruise velocity by the horsepower per ton of payload.

Conclusions

It appears that the air-cushion vehicle offers considerable potential as a means of off-the-road transportation. The superiority of the air-cushion vehicle over the wheeled vehicle in off-the-road operation is evident. Nearly all the terrain restraints—such as mud, snow, ice, marsh, water—are overcome. In addition, the ability to move cargo faster, and in many cases more efficiently, is an attractive feature.

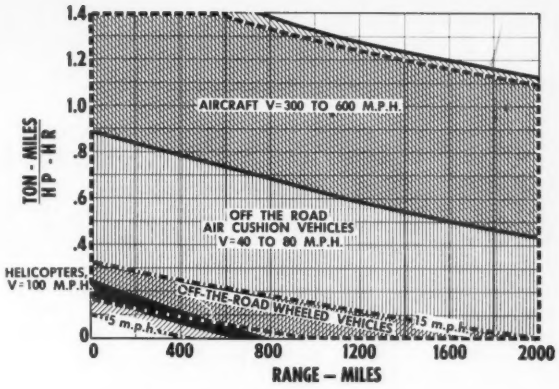

Fig. 12. Summary of working rates.

Undoubtedly, aircraft will nearly always enjoy a speed advantage over air-cushion vehicles. However, the air-cushion vehicle appears to be competitive in the ability to perform as a logistic carrier in terms of ton-miles per horsepower-hour. In addition, the air-cushion vehicle does not require the extensive terminal facilities.

Air-cushion vehicles offer a significant transportation potential in comparison to the helicopter. However, when it is necessary to get in and out of remote areas, the helicopter is clearly superior. Because of these respective capabilities, these two transport systems are complementary rather than competitive.

In summary, it would appear that the eventual acceptance of the air-cushion vehicle as a means of off-the-road transportation will depend upon the ability to achieve these attractive performance characteristics with a vehicle that is safe, reliable, and easy to operate and maintain. This will require the development of an adequate control system and inherently good stability characteristics. Further, acceptable solutions to the operational problems of dust and spray must be found.

Symbols

$hp._L = hp._{lift}$	= horsepower required for lift
$hp._D = hp._{drag}$	= horsepower required for drag
h	= vehicle clearance height above ground, ft.
l	= vehicle perimeter, ft.
P_{f_∞}	= ideal hovering power required out of ground effect (typical of a ducted fan), ft.lb./sec.
P_T	= theoretical hovering power required in ground effect, ft.lb./sec.
S_J	= jet area measured normal to flow, ft.^{2}
S_b	= base area, ft.^{2}
S	$\simeq S_J + S_b$, ft.^{2}
V	= velocity, ft./sec.
Δp	= base pressure (gage), lb./ft.^{2}
θ	= jet discharge angle, measured from vertical, negative inward

Subscripts

1	= conditions at start of cruise
2	= conditions at end of cruise
x	= conditions at *vena contracta* in flow from plenum chamber

(*Continued on page 65*)

Propeller Effects on the Stability and Control of VTOL Aircraft

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WITH THE advent of high power to weight ratio turboprop gas turbines, much effort has been expended in the development of VTOL-STOL aircraft. The majority of these machines employ propellers or articulated rotors; specifically, the Hiller X-18 and Vertol Model 76 tilt the propellers through approximately 90° in the process of transition from either hovering to level flight or level flight to hovering.

In the past, all work on propellers in inclined flow has been done at very low inclination angles[1-5] with the exception of three notable reports,[6-8] although it was felt that for purposes of evaluating longitudinal stability derivatives there are limitations to these latter reports.

Description of Forces

The primary forces considered are shown in Fig. 1. Normal force N_p, which acts through the hub, parallel to the propeller plane, is caused by a difference in the torque-producing force between the advancing blade and the retreating blade. If the disc were perpendicular to the free stream, the resultant flow seen by a rotating blade—i.e., the vector sum at the rotational velocity plus the inflow or free-stream velocity—would be uniform.

However, if the disc were parallel to the free stream, it is obvious that for a simple case the advancing blade at $\Omega = 90°$ will be subjected to (neglecting induced velocity for the moment) a velocity equal to the rotational velocity plus the free-stream velocity, whereas the retreating blade at $\Omega = 270°$ will see a velocity equal to the rotational velocity minus the free-stream velocity. From Fig. 3, it can be seen that the resultant lift and drag forces on any propeller blade section consist of an in-plane torque-producing force Q and a perpendicular thrust-producing force T.

Therefore, in inclined flow, $A' > 0$, the advancing blade will experience a greater torque-producing force than the retreating blade, the result being a net force N_p parallel to the disc in the direction of increasing A'.

Yawing moment M_y, which acts around the hub in the Y-Z plane by a similar argument, arises from the difference in thrust-producing forces experienced by the advancing and retreating blades. However, this moment is of little interest in stability and control work because it can be effectively cancelled either by contrarotating propellers for a single nacelle aircraft or by opposite rotation of propellers in two and four nacelle aircraft, which are the most common types under study today. It is of considerable magnitude and obviously must be weighed in propeller and power shaft design work. But for this paper, it will not be considered further.

Pitching moment M_p, which acts around the hub in the X-Z plane (perpendicular plane to the disc), has, in the past, been considered to be small and hence, in many stability analyses, has been neglected. Inspired by the NASA,[8] extensive tests were performed which indicated that this was not the case and that the pitching moment was of the same order of magnitude as the yawing moment.

The existence of this moment cannot be explained by cyclic loading considerations in the same manner as was done previously with normal force and yawing moment because it acts around an axis (Y-Y) perpendicular to the X-X axis which is the symmetry dividing line between the advancing and retreating side of the propeller disc. Referring to Fig. 3, and now considering the induced velocity V_i, it is evident that the blade angle of attack is dependent not only on the rotational velocity and the free-stream velocity but also on the induced velocity.

The research investigation described in this paper was sponsored by the Office of Naval Research.

An experimental investigation of forces and moments acting on a propeller was conducted over a range of tilt angles from 0° to 90°. It was found that the normal force and pitching moment acting at the propeller hub are of considerable magnitude and must not be neglected in any analysis of VTOL-STOL aircraft which must incline the propeller over 15° for take-off and landing. Thrust variation with forward velocity and pitch angle is another factor which must be considered in any analysis of tilt-wing or tiltable propeller aircraft configurations.

Attempts were made to predict these forces and moments analytically, but it does not appear that any known method provides the necessary accuracy and reliability.

The majority of propeller analyses, in the past, have employed either the Goldstein or Theodorsen approximations for determining the induced velocity. The former is limited to a lightly loaded rotor, while the latter appears to be quite satisfactory for the normal range of propeller operation—that is, $A' < 15$—where one can assume that the propeller-wake proceeds axially downstream from the disc.

However, for the case of a propeller inclined to the free stream, this assumption can no longer be made. From smoke studies and velocity traverse data, it is evident that the free stream has a strong effect on the position of the wake. As a first estimate, it appears that the wake is swept back to a much greater degree than that indicated by a simple vector summation of the free-stream and slipstream velocities. Noting reference 5, it was found that the theoretical method of estimating normal force, employing the Theodorsen method for predicting the induced velocity, consistently underestimated normal force for angles as low as $A' < 20°$. The induced velocity approximation appears to be the one serious shortcoming of this analysis.

Discussion of Test Results

From work conducted in the Subsonic Laboratory of the James Forrestal Research Center, the variation of the three primary propeller components which affect the longitudinal stability of tilting propeller VTOL-STOL aircraft with forward velocity and tilt-angle is shown in Figs. 4, 5, and 6. Neglecting the dotted curves, for the moment, and arbitrarily choosing two representative flight conditions, the relative magnitude of these forces can be shown very easily. Since

$$C_T/C_{N_P} = T/N_P \qquad N_P = T\cdot(C_{N_P}/C_T)$$

For normal force

$$C_T/C_{M_P} = TD/M_P \qquad M_P = T\cdot D\cdot(C_{M_P}/C_T)$$

For pitching moment

For a tilt-wing aircraft developing a take-off thrust of 40,000 lbs. employing two 18-ft. propellers rotating in opposite directions at 1,000 r.p.m.:

Table 1.

J	A'	V (fps)	C_{N_P}/C_T	C_{M_P}/C_T	$N_{P_{total}}$ (lbs.)	$M_{P_{total}}$ (ft.lbs.)	T_{total} (lbs.)
0.2	60°	60	0.0397	0.0397	1,590	28,600	40,000
0.4	45°	120	0.1134	0.0412	3,410	22,280	30,000

From Table 1, it appears that both normal force and pitching moment reach quite high values for the given

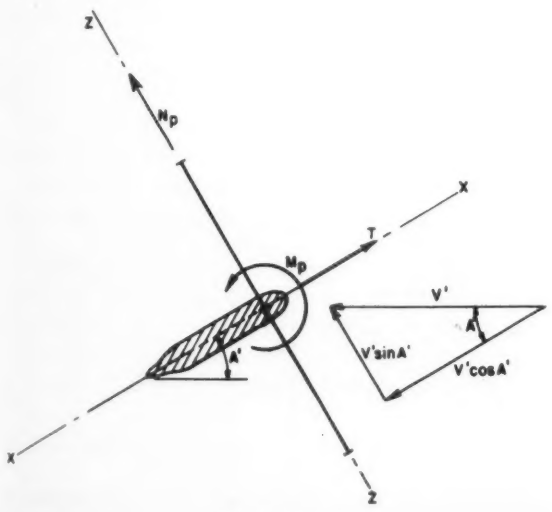

Fig. 1. Side.

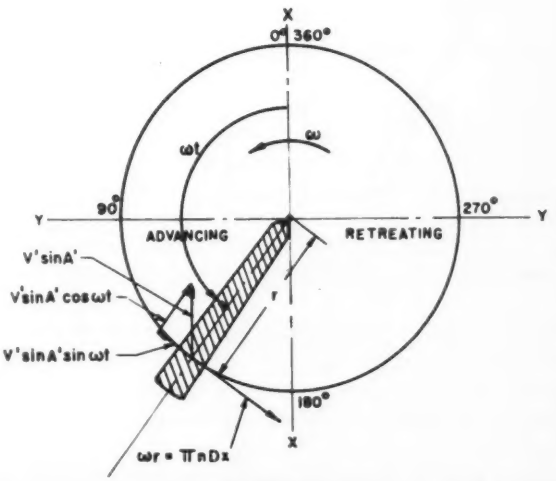

Fig. 2. Front.

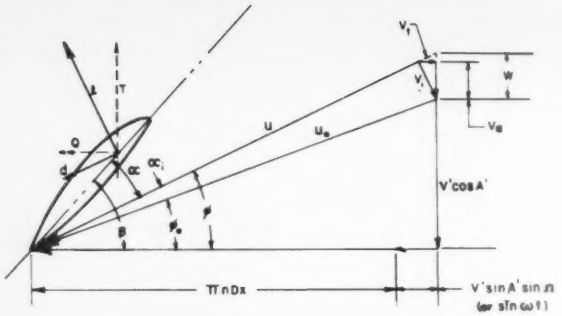

Fig. 3.

set of conditions. These values, of course, are only rough approximations, although on the conservative side, since from the dotted curves on Figs. 4, 5, and 6 it is evident that placing a wing behind the propeller increases the magnitude of all three components. These curves were obtained from a complete model, Fig. 7, and so include possible interference effects—arising from the fuselage.

The large increase in propeller normal force (80–90 per cent) and the increase in propeller pitching moment (40–50 per cent) in the presence of the wing can be largely attributed to the fact that the velocity through the top-half of the disc (above the Y-Y axis) is greatly increased owing to the effect of the wing[8]—that is, the upwash of the wing is added to the free stream which produces a higher velocity through the upper half of the disc than through the lower half. This tends to decrease the angle of attack of the blades moving through the upper half, thus reducing thrust and causing a pitching moment M_p. The higher velocity also increases N_p, as previously explained.

The increase in thrust (C_T, Fig. 4) with J (forward speed) in the hovering configuration is a result of two effects:

(1) Change in local blade angle of attack arising from a decreasing induced velocity.

(2) Change in the mass flow acted on by the propeller.

The first of these effects can be easily seen by application of momentum and blade element analyses. (See Fig. 8.)

Blade element:

$$\alpha = \{\beta - [(V \sin B' + v)/(\Omega r + v \sin \psi)]\}$$

$$\psi = \omega t$$

Assume that B' is small such that

$$\Omega r + V \sin \psi V \cos B' = \Omega r + V \sin \psi$$

Also assuming that blade drag is small and that the thrust force results from blade lift such that

$$T \cong L = C_L q S$$

Thus

$$dT = \frac{dC_L}{d\alpha}\left[\beta - \frac{V \sin B' + v}{\Omega r + V \sin \psi}\right] \times (1/2)\rho\,[\Omega r + V \sin \psi]^2\, b dr d\psi$$

$$T = \frac{1}{2\pi}\int_0^{2\pi}\int_0^R \frac{dC_L}{d\alpha}\left[\beta - \frac{V \sin B' + v}{\Omega r + V \sin \psi}\right] \times (1/2)\rho[\Omega r + V \sin \psi]^2 b dr d\psi$$

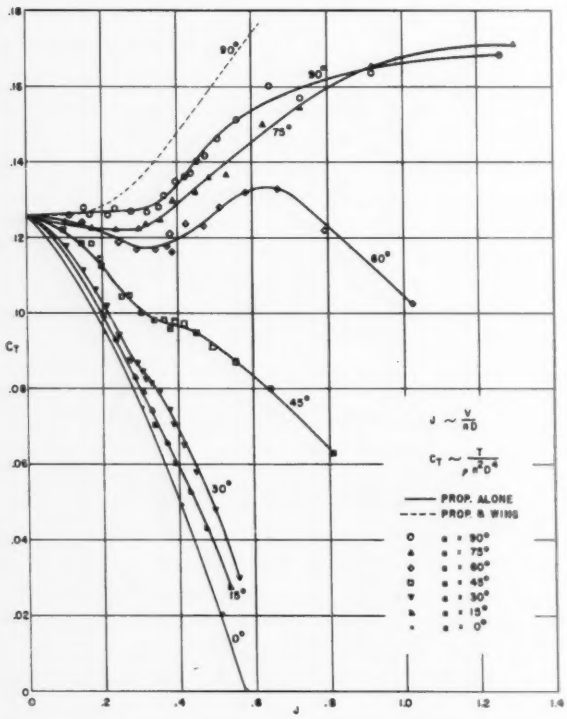

Fig. 4. C_T vs. J. (Three-blade propeller, act. factor = 100, C_{L_D} = 0.5, $\beta 75R$ = 12°.)

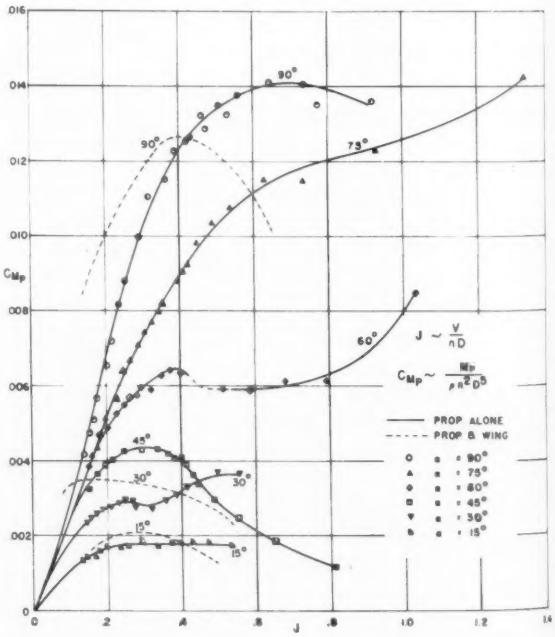

Fig. 5. C_{M_P} vs. J. (Three-blade propeller, act. factor = 100, C_{L_D} = 0.5, $\beta 75R$ = 12°.)

Integrating and substituting

$$T = C_T[\rho(\Omega R)^2 \pi R]$$

$$\sigma = b/\pi R$$

$$dC_L/d\alpha = C_{L\alpha}$$

$$2C_T/C_{L\alpha}\sigma = (\beta/3) - [(V \sin B' + v)/2\Omega R]$$

In the hovering configuration $B' = 0$, v is quite large and the thrust is determined by $(\beta/3) - (v/\Omega R)$. With the beginning of transition, B' and V increasing, the effect of changes in these two components is small; however, the induced velocity drops off very rapidly thus acting to decrease the second term, hence increasing thrust. With further increase in forward speed, hence a greater B', the induced velocity becomes quite small, and $V \sin B'$ begins to increase such that the second term slows its decrease and begins to increase, therefore decreasing thrust. In conjunction with this blade-element explanation, a momentum consideration is, What mass flow or cross-section area does one employ? From smoke studies, it appears that in the transition region a larger mass of air is affected by the disc than would be expected.

$$T = M\Delta V = \rho A[(V \sin B' + v)^2 + (v \cos B')^2]^{1/2} 2v$$

Thus, as v decreases, M increases somewhat faster, therefore increasing thrust momentarily; this effect ceases as v becomes smaller with a further increase in $V \sin B'$.

Test Equipment

The 14-in.-dia. 3-bladed aluminum propeller was driven by a 1/2-hp. d.c. motor suspended on two strain-gaged beams totally independent of the support sting in the prop-alone case or the nacelle in the prop and wing case. This was found to be a most successful method of extracting the desired propeller forces and moments.

The repeatability of the data was excellent, and the only serious scatter was found in the normal force. It was felt that this was due in part to the large change in C_T with tilt angle. (Note Fig. 4 where there is a large change in C_T for tilt angles in the 30° to 75° range.)

Considerable concern was expressed about the validity of the data obtained in the low Reynolds number range, 150,000 to 260,000. It is felt that the scale effect is small since the C_T versus J curve for $\alpha = 0°$ compares within 5 per cent of full-scale data for similar propellers. This is further borne out by reference 10 where it is indicated that there is no significant change in propeller performance over a large Reynolds number range.

Tests were also conducted at blade pitch angles other than $\beta_{.75R} = 12°$, but these results are as expected, decreasing forces with decreasing β, and will not be presented here.

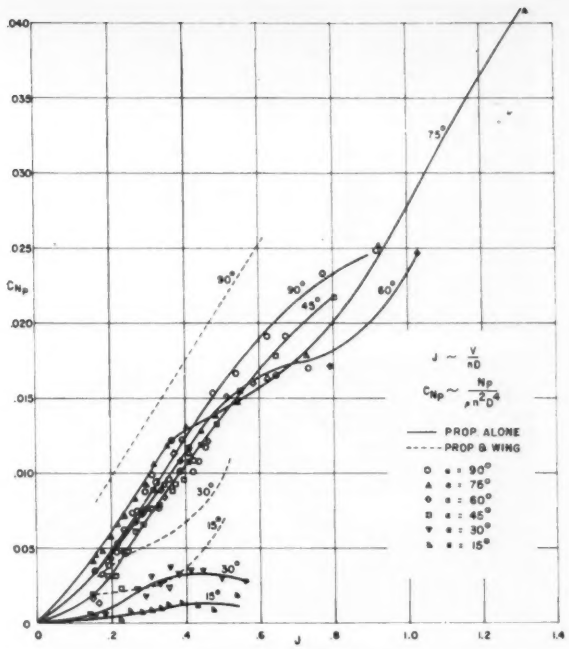

Fig. 6. C_{N_P} vs. J. (Three-blade propeller, act. factor = 100, $C_{L_D} = 0.5$, $\beta_{.75R} = 12°$.)

Analytical Prediction of Normal Force and Pitching Moment

From reference 5, an expression for normal force coefficient C_N, where $C_N = N_p/qS$ (q = free-stream dynamic pressure, and S = disc area) is obtained

$$C_N = \frac{B}{4\pi R_t} \int_{x_3}^{1.0} (C_q)_{\Omega=90°} - (C_q)_{\Omega=270°} \, bdx$$

where

$$C_q = C_l \left(\frac{V'}{V}\right)^2 \frac{\cos^2 A'}{\sin \phi} \left[1 + \frac{\bar{w}}{2} \cos^2 \phi\right]^2 \times \left(1 + \frac{C_d}{C_l} \cot \phi\right)$$

$$\bar{w}/2 = W/(V' \cos A')$$

which is the induced velocity obtained by the Theodorsen approximation.[11]

This induced velocity is critical in the above calculation. It will be noticed, Fig. 3, that ϕ and α are both affected by the magnitude of this term. For fixed β and $V' \cos A'$, any increase in W (or $\bar{w}$) will decrease α, the blade angle of attack, thus changing c_l, and will also increase ϕ. Obviously, if W were negative, there would be an even greater change in the above quantities.

This induced velocity, neglected to some extent by those doing propeller work, has long been a problem in helicopter rotor research.[9, 12] Since it appears to be a dominant factor in the normal force equation, it will also be important in thrust calculations. But in neither of these is the induced velocity the sole cause of the force. In analyzing propeller pitching moment, it

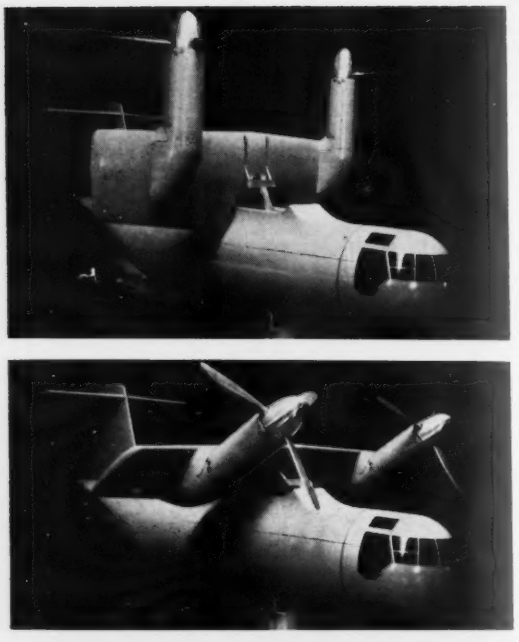

Fig. 7.

becomes apparent that this moment is caused solely by the variation in the blade loading from the front to the rear of the disc as this loading is changed by the induced velocity flow field. From smoke studies performed at the Forrestal Research Center,[13] it is evident that the induced velocity is not uniform over the disc, and it is possible that it can assume negative values

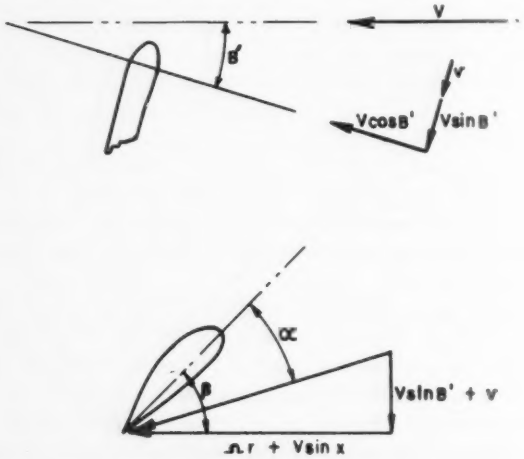

Fig. 8.

over the rear portion of the disc. Conventional means of integrating back to the disc from the final wake are useless here because one does not know the configuration of the final wake. For the $A' = 0$ case, where the disc is perpendicular to the free stream, Theodorsen's work appears to be quite accurate, and a method proved by Kawada[14] in 1939 also leads to a satisfactory prediction of the induced velocity at the disc. But for $A' \gg 0$, these methods can no longer be employed because they assume a final wake configuration which is no longer true.

Unfortunately, it is beyond the scope of this paper to indulge in further attempts at predicting this induced velocity. The purpose here is to present what is believed to be accurate data of the propeller forces which affect the longitudinal stability of VTOL-STOL aircraft in a useful nondimensional form so that it may be applied by future designers of these machines. Suitable correction factors to adapt these data to any propeller can be found in reference 6 which presents corrections for *number of blades*, *activity factor*, and *airfoil section* ($C_{L_{des.}}$). These correction factors can be applied to C_T, C_{N_P}, and C_{M_P} with little loss of accuracy since these components all depend almost directly on the propeller loading, which, in turn, is determined, approximately, by the above three factors.

If more precise data are necessary, it would appear far easier to construct a scaled propeller and have it tested through the desired range of tilt angles.

Conclusions

The complicated flow behind a propeller in inclined flow has invalidated all known theoretical methods to predict accurately aerodynamic forces on an inclined propeller. Three of these forces, thrust, normal force, and pitching moment, have been thoroughly investigated experimentally as to their causes and magnitudes. The existence and variation of these forces cannot be safely neglected in the design of VTOL-STOL aircraft. It is possible from the given data to obtain an approximate prediction of such forces which might be used advantageously in preliminary design work.

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(*Continued on page 64*)

There is no such thing as a fatigue failure. Generalized aircraft spectra are not sufficient to determine fatigue failure rate, so structural component and element spectra must be derived. These spectra must define two conditions—the past loading history of the element and the present probability of exceeding a given load.

The Statistical Basis of Loading Spectra for Fatigue Design Criteria

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THE BASIC OBJECTIVE of structural design criteria is to formulate requirements for a structure which will reliably attain a specified operational life. Quantitative definition of *how* reliably *what* life is to be attained is a difficult procedure. Implementation of the requirements in a structure, with confidence that the requirements will, in truth, be met, is an extremely challenging task.

Evolution of Present Structural Design Criteria

In the past, structural design criteria did not explicitly state the quantitative requirements for reliability and life; instead, the typical criteria defined loading conditions, which, if met, resulted in extremely high structural reliability over the lifetime of all aircraft designed to those criteria. The criteria were the end result of past experience. Any failures, other than occasional random failure, resulted in criteria modification. New developments such as abruptly checked maneuvers and inertial coupling conditions were added as necessity dictated and outmoded conditions were gradually removed. This empirical approach to structural design criteria has, in general, proved sufficient, until recently, for the needs of designers and the service administrators of structural design policy. However, certain anomalies have always been present which resulted in some airplanes being overdesigned and others underdesigned.

Need for Probabilistic Criteria

Recent rapid advances in weapon system design have resulted in radical changes in structural design requirements, so much so that a change in criteria philosophy appears to be an obvious necessity. To this author, a probabilistic approach to design criteria is the only rational concept. The big difficulty is to find a practicable solution to the problems that arise while reducing theory to practice.

At first blush, use of a probabilistic philosophy is a radical departure from the past, with the revolutionary changes in design concepts currently in progress justifying corresponding revolutionary changes in criteria concepts. However, the change in criteria philosophy is more apparent than real. Structural reliability or probability of failure has always been implicit in previous regulations. The qualitative probability input to criteria formation has been either success in performing the desired mission or what someone's judgment indicated to be "too many" failures. Furthermore, fatigue has always been a consideration in past criteria—occasionally explicitly, usually implicitly. Examples are fitting factors—knowledge of what constitutes good detail design in matters of sharp corners, scratches, avoidance of brittle material, etc., and designing to normal operating stresses below the endurance limit.

Adventitious and Fatigue Failures

Furthermore, there is a little realized but close relationship between the adventitious, or discrete, failure and the fatigue failure. Adventitious failures are the end point of the range of fatigue failures possible from the millions of cycles of low amplitude loading to the few cycles of extremely high amplitude loading. Also, "fatigue" failure in any structure always occurs from a single application of some load. This load may be a relatively low load—the same magnitude as has

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been continuously applied for millions of cycles—but it nevertheless is a discrete load that finally administers the *coup de grace* to the structure. In this case, most of the original strength of the material has been lost because of fatigue deterioration. Similarly, the final failing load may be a relatively large load that occurs after only a small amount of fatigue damage has been inflicted on the structure. Finally, and obviously the end point of this sequence of possibilities, failure may come from a single application of very high load before any fatigue damage has been done. Thus it is apparent that there is no fundamental difference between adventitious and fatigue failures. The one blends into the other with no evident line of demarcation. It is a rather startling concept, but, in fact, it can be said that *there is no such thing as a fatigue failure.* There are only adventitious failures at different magnitudes of loading, the magnitude of the failing load being a function of the loading history (both magnitude and sequence) and the consequent amount of fatigue damage incurred.

Need for Change in Criteria Emphasis

From the foregoing, it is evident that past structural design criteria established adequate qualitative coverage for a high degree of structural reliability for both adventitious and "fatigue" modes of failure. Adventitious failures were held to a minimum by specifying limit and ultimate conditions that rarely occurred. Fatigue failures were limited by indirect methods as described previously. Both modes of failure were guarded against by implicit methods which resulted qualitatively in the desired structural reliability without ever quantitizing either the reliability level or the operational life.

Past criteria emphasized the prevention of adventitious failures while only obliquely treating the problem of fatigue failure. The situation with which designers are now faced requires no new concepts. The old tried and true concepts are completely adequate. All that is needed are methods to rationalize the criteria objectives by quantitizing structural reliabilty for a given life and by changing emphasis from the adventitious failure mode to the fatigue mode.

Initial Conclusions

Rationalizing and quantitizing the criteria may require initially a mixture of rational and empirical requirements until all the data and analytical techniques necessary for the completely rational approach are available.

Establishing Statistical Criteria

With the foregoing as a suitable background for studying the problem of providing a statistical basis for fatigue design criteria, it is now appropriate to examine the rationale for such criteria.

Establishing a fatigue design criteria is a fantastically complex undertaking if a thorough job is to be done. The undertaking will be approached as follows:

(1) Determine the parameters needed to establish the required loading spectra.

(2) Investigate the sources for establishing such parameters quantitatively.

(3) Develop analytical techniques for synthesizing the loading spectra for any new aircraft system from the parameters established for past systems or from a rational analysis of the new mission requirements.

(4) Formulate structural design criteria embodying the principles established in the preceding steps.

Parameters Required for Loading Spectra

At present, there is no complete study defining the parameters needed to establish the required loading spectra. Much work has been accomplished in this field, but much remains. A few pertinent observations can be made.

Fatigue is a condition which occurs at localized points on the structure. It is, therefore, a function of the loading history and the material at that point. Determination of the load at a point requires knowledge of the complex distribution of loads on an aircraft for a given set of aircraft parameters. Performing these calculations for a few discrete conditions as required by present criteria is a major undertaking. To do it for multiple combinations of all the parameters defining the flight conditions of the aircraft is a colossal endeavor.

At this point in the discussion, it seems proper to review the parameters that define the magnitude and distribution of loads on an aircraft. In 1954, a Special Statistical Maneuver Loads Panel of the Loads Subcommittee[1] recommended that statistical data on eight basic aircraft parameters be obtained from operational usage. These eight parameters were the three linear accelerations, the three angular accelerations, air speed, and altitude. With these parameters known, the motion of the airplane and the aerodynamic conditions determining the distribution of load are completely defined. It is in the statistical definition of these eight parameters that difficulty is encountered. Many of the statistical functions of these parameters are themselves functions of some or all of the other seven parameters. This means the probability functions are multidimensional and, as a result, extremely difficult to define and manipulate in probability calculations.

To define the load on a specific structural component on the aft fuselage, it is generally necessary to know (1) the horizontal and (2) the vertical tail load plus (3) the inertial loads for the particular flight condition being investigated. Each of these three loads is a function of the eight basic parameters defined previously, plus other derived parameters such as the angular velocities, Mach number, and airplane lift coefficient. Thus each of the three loads is a complicated function of many parameters, and the load on the fuselage component is the sum of the three complicated functions. The complication inherent in the calculation of the single load is compounded when

the spectrum of this load is desired and it must be derived from knowledge of the statistics of each of the parameters entering into the calculation of the desired load. Some idea of the scope of the problem can be obtained from the work by Bouton and Scrooc[2] for a two-element structure and by Bouton and Shirley[3] for a 16-element structure.

The immensity of the task is compounded again when the spectrum of the loading at a single point is expanded to include the thousands of points all over the aircraft. Spectra for these thousands of points are needed because each of these points must be individually investigated to determine the fatigue failure rate at each point and, from this, the airplane failure rate and structural reliability. This, then, completes the picture of what parameters are needed to define the loading spectra for fatigue analysis of an aircraft.

Sources for Spectra Parameters

The data sources for establishing the above-mentioned parameters are many and varied. Past work on the subject is well known to aeronautical engineers and will not be considered at length here except to mention a few. Work such as that done by Doolittle,[4] Rhodes,[5] Donely,[6] Reynolds,[7] Gray,[8] Press and Mazelsky,[9] Mayer and Hamer,[10] Hamer, Huss, and Mayer,[11] Sissenwine,[12] Barrett,[13] Clementson,[14] and others has contributed much to the store of statistical knowledge.

Despite all these efforts in the past, we simply do not have enough information to design an aircraft on a statistical basis. From the best information available there is no indication that any operational airplane has used statistical data as the sole basis for structural design. Another indication of this is the action taken by the NACA Loads Subcommittee in 1954. A Special Panel was established to recommend to the Subcommittee what action should be taken regarding statistical maneuver loads. Included in the recommendations of the Panel, which were endorsed by the full Subcommittee, was one that a joint military-NACA program be established to measure statistically eight parameters chosen to establish the motion of the aircraft and the aerodynamic conditions during the motion. These eight parameters were the three angular accelerations, the three linear accelerations, air speed, and altitude. Also, the Panel recommended that NACA do more research on fundamental criteria problems.

This eight-channel program gathered momentum slowly in the years following until the recent impetus, given by the fatigue failures described in previous papers, necessitated quick action on the subject. As a result, money became available to implement the program. An eight-channel recorder was brought to the prototype stage, and the remainder of the program, originally suggested by the Special Panel, is currently being implemented. Reduction of the eight-channel data to desired form is being implemented as a joint Air Force-Navy-NASA program. A facility with a large digital computer and necessary analog equipment will be put under contract in the near future. This facility will be operated under cognizance of the Bureau of Aeronautics. It is expected to require full-time operation simply to keep up with the data received from the 240 Air Force eight-channel recorders and the 50 Navy recorders. This information will all go into a common pool and will be accumulated as appropriate to class of aircraft, mission, etc. Some idea of the magnitude of the job is that the present data reduction program established over 13,000 separate combinations of flight conditions that will be recorded and accumulated for statistical analysis.

Norair was awarded a contract by WADC to review the eight-channel program already established, recommend improvements, and determine the ultimate objective of a structural criterion. This study is principally directed toward maneuver loads. However, the end product should be one in which both maneuver and gust loadings can be fitted together in determining the loading spectrum for any given type of aircraft. There are many other studies in the total WADC program. One of major interest, in connection with the subject of this paper, is the program by Douglas to review all of the past data and determine applicable methods for converting these data into loading spectra.

In addition to the eight-channel program, the Air Force is instrumenting 2,400 airplanes for a VGH program set up explicitly to obtain fatigue information on gusts and landing conditions. Additional data have been obtained from airplanes such as the B-47 and FJ-4. Furthermore, NASA is currently in the final stage of a report on the F-84, giving a large amount of statistical data. In addition, F-100 data are being worked up on the basis of the information that will be available from the eight-channel program. This analysis is to show what kind of information can be derived from the eight-channel recorder program.

In recent years it has become apparent that information on low-altitude gusts is necessary for military operations, and various procedures have been followed to obtain these data. Norair had a contract to measure low-altitude gusts with the F-89 and published these data in reference 13. Subsequent to this, WADC contracted with Douglas to obtain low-altitude gust data on the RB-66. This operation is currently in progress. Gust analysis has become, almost universally, one of establishing the power-spectral density of the atmosphere. This stems from work done by Press and Mazelsky,[9] Clementson,[14] Bendat,[15] and others.

There are many other sources of statistical loading data for aircraft, but time prohibits noting them all. Unfortunately, much of the early statistical data is not in a form amenable for use in establishing fatigue spectra. The reduction of all of the statistical data that have been and are being generated into maneuver, gust, and ground loading spectra is a big enough problem to warrant a paper on this subject alone.

Synthesis of Spectra for New Systems

In the opening paragraph it was stated that "the basic objective of structural design criteria is to formulate requirements for a structure that will reliably attain a specified operational life." In order to formulate these requirements, *how* the spectrum should be defined in order to accomplish *what* purpose must be known. It follows that a rational loading spectrum is one which, if properly designed for in the structure, will result in a structure which has the required lifetime. The determination of this spectrum is, on the surface, relatively easy, but in practice it will be extremely difficult.

It seems to be a general belief that a simple spectrum consisting of frequency of attaining a load factor as a function of the load factor is all that is needed to define the fatigue environment for an aircraft structure. This is simply not the case. Fatigue is a condition which occurs at a point in the structure and, therefore, must be the result of the lifetime loading history at that point. It is a truism that no structural component of any aircraft has ever failed in fatigue because the frequency of occurrence of various center of gravity load factors has been excessive. There is no way to determine the fatigue life of a composite structure except by determining the fatigue life of the basic structural elements of that composite structure. This requires knowledge of the loading spectrum of each of those basic elements.

Loading spectrum is used here with a much less restrictive meaning than is common. "Loading spectrum" is assumed to mean not only the frequency of occurrence of a given load but also the type of load-tension, compression, shear, etc., the order of occurrence of these loads, and the probability of encountering a different frequency of occurrence. This definition of loading spectrum and an understanding of the fatigue process in aircraft leads to another interesting observation: In order to determine the fatigue life of a structural element it is necessary (1) to define the loading history of that element at any time during its life, and (2) to determine the probability of encountering loads of various magnitudes at that particular time in the element's history. The statement above contains the inherent assumption that fatigue life is defined—not as a number of hours that a structural element will survive, period, but—as the probability that the element will survive any given number of hours.

With these ground rules understood to be established, the analytical techniques necessary to define the loading spectrum for an aircraft structural element may be explored. First, it should be said that designers, analysts, and those responsible for establishing criteria do not fully appreciate the immensity of the task of specifying and being able to develop the loading spectrum for each of the myriad structural elements. This spectrum is the end result of a long-chain of calculations starting with the determination of the spectra of various aircraft parameters. These airplane parameter spectra, in turn, must be derived from definition of the mission of the aircraft.

The starting point of fatigue design criteria is obviously an abundance of statistics. It is assumed that the Sources for Spectra Parameters, discussed in a previous section, plus other new sources of data, will continue to develop statistical data of the type described in the section on Parameters Required for Loading Spectra. Someday there will be sufficient data available to meet the requirements of the analysis described in this paper. When that day arrives, it is hoped that the capability of the analyst to utilize such data will have increased commensurately. To date, there have been many researchers in this field of fatigue design criteria, but each one has tackled only a small portion of the total problem.

Mayer and Hamer[10] have considered the problem of rationalizing the load spectrum from knowledge of the mission of the aircraft and the utilization of the aircraft in various phases of that mission. Bouton and Scrooc[2] and Mayer, Stone, and Hamer[16] have examined the problem of deriving, statistically, major component loads. Bouton and Shirley[3] and Hilton and Feigen[17] have looked into some aspects of the loading spectrum for structural elements. References 2, 3, and 17 and English,[18] Freudenthal,[19] Pugsley,[20] and van der Neut[21] all analyze the failure rate of components and from this derive the total failure rate of the aircraft. Some of these references include the effects of scatter in strength properties while some do not. Reference 16 takes up the question of the effect of confidence limits on the load spectra. Reference 19 studies the probability of failure under fatigue conditions.

Each of the reports mentioned above only begins the investigation necessary before the techniques described can become routine tools of the analyst. No one has performed the task of integrating all these partial analyses into a complete analysis of structural reliability under fatigue failure conditions. Until such a study is undertaken and all the requirements for loading spectra are defined, there will be some uncertainty as to whether the present efforts are progressing in the proper direction. Thermal effects on structural reliability are considered to be beyond the scope of the present paper.

At this time, it is of interest to consider the spectra presented in the proposed fatigue design criteria, MIL-A-8866. The -8866 spectra represent a considerable advance in the problem of designing rationally to avoid fatigue failures. However, these spectra and the other requirements of -8866 are not sufficient to obtain the freedom from fatigue failures that is desired. Consider the case of a population of single elements, each of which has a 50 per cent probability of survival for a given time. Under these circumstances, approximately 63 per cent of the elements will have failed at the end of the given time. By analogy this can be extended to the failure rate of aircraft designed for a specified number of flight hours and the load factor spectrum of -8866. Since the -8866 spectra represent averages, it might be expected that 63 per cent of the aircraft designed to MIL-A-8866 will fail sometime before the specified number of hours have elapsed. This assumes that the

fatigue analysis is precise and that critical components are not replaced. The average time to fail may not be much less than the specified time, so the resulting effects on fleet cost, combat readiness, spares requirements, and model life span may be small. Nevertheless, the average life will be less than the specified life, even with perfect analysis techniques.

To summarize, the requirements for synthesizing loading spectra for new systems and the problems involved in calculating such spectra appear to be overwhelming.

Formulation of Fatigue Design Criteria

The objective of a fatigue design criterion is to provide an aircraft structure which will not fail, except in minor, inconsequential, easily repairable ways, during the lifetime of the aircraft which performs its specified mission. Regardless of whether or not the state of the art can provide such capability, this objective should be the stated intent of the criteria. If, as, and when the capability is developed to synthesize loading spectra and to analyze accurately the fatigue strength and reliability of the structure, then fatigue design criteria can be defined well enough so that the designer and analyst can eliminate the large majority of fatigue failures.

Because of the present state of the art, the actual specification of fatigue design criteria should be stated in as general terms as possible with specific methods for accomplishing the stated objectives left to the designer. It is suggested that the specification contain only the basic requirements such as desired life, quantitative definition of structural reliability, policy decisions on matters of the relation between structural reliability and total system reliability and performance, need for establishing secondary missions, etc. A fundamental decision must be made on whether there shall be one requirement for average life and another requirement for safe life. Further, it is suggested that a *Criteria Manual* be published which discusses and, as appropriate, presents the basic numerical data required to synthesize loading spectra and acceptable methods for performing the fatigue analysis. Criteria which result from considerations of optimizing the structure have no place in the criteria specification, but optimization procedures could logically be included in the *Manual*.

It should be understood that, no matter how carefully the fatigue design criteria are phrased, the state of the art is not such that all fatigue failures can be eliminated. Elimination of the majority of fatigue failures is a more realistic objective. If the criteria are complicated too much in the vain attempt at perfection, losses rather than gains may result in the fight against fatigue failures.

Above all, the fatigue design criteria should not take such form that tomorrow's aircraft are being designed to overcome yesterday's problems.

Conclusions

The following summarizes the major subjects discussed in this paper:

(1) Previous specifications for structural design criteria presented fatigue requirements qualitatively and implicitly. Quantitative and explicit requirements are needed now.

(2) Elimination of the majority of fatigue failures is a reasonable objective for fatigue design criteria, but complete elimination is not.

(3) The relationship between adventitious and fatigue failures is discussed. It is noted that, literally, there is no such thing as a fatigue failure.

(4) Synthesis of spectra is a colossal task, but it can be done.

(5) There is still need for a large-scale program to gather statistical data for loading spectra. Much more research is necessary on methods of utilizing the statistical data in the design criteria.

(6) Statistical data on the eight parameters established for the present eight-channel data recording program form the minimum basis for rational fatigue criteria.

(7) The concept is established that fatigue is a localized condition so loading spectra for a myriad of structural elements must be the end product of the basic loading spectra for the complete aircraft.

(8) The loading spectra really must establish two functions. First, the past history of an aircraft at any time in its life must be determinable statistically in order to determine the probable strength level (fatigue damage) of the structural elements at all times during the lifetime of the aircraft. Second, the probability of encountering a given magnitude load at any given time in the history of the component must be known in order to compute the probability at any given time. The aircraft probability of failure and its inverse, structural reliability are the sum total of all the probabilities of failure during the previous history of the aircraft.

(9) Many decisions are needed regarding fundamental questions of design objectives.

(10) It is suggested that a *Fatigue Criteria Manual* be established to present numerical data on the various phases of aircraft utilization and acceptable procedures for synthesizing the loading spectra.

(11) Fatigue analysis with the loading spectra MIL-A-8866 will necessarily be imperfect. Component and elemental load spectra cannot be determined with only load factor spectra defined. The average life resulting from use of the present spectra will result in fatigue failures at some time less than that specified.

(12) Some new concepts are introduced and some old ones restated. Some of these concepts may be controversial. In any event, it is hoped that presentation of these concepts will stimulate rational thinking on the subject.

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Evaluation of Thermal Problems at Relatively Low Orbital Altitudes

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AN ORBITING vehicle is affected by four significant heat sources—direct solar radiation, solar radiation reflected off the earth and atmosphere, energy radiated from the earth (Fig. 1), and heat produced within the vehicle. Cosmic ray heating and energy input from meteoric dust are considered negligible.

Radiated heat produces relatively large temperature fluctuations on the exposed wall surface of the vehicle. For example, if an isolated point on the skin of a vehicle in a 50 per cent day–50 per cent night, 300-mile orbit is assumed to have an emissivity of 0.4, the temperature will oscillate between a low value approaching absolute zero and a high value of nearly 440°F. These figures represent upper and lower bounds since they apply to the most critical locations and neglect all heat transfer other than outward radiation from the exposed surface.

There are two obvious ways of decreasing the amplitude of the temperature fluctuations—imparting a rotational velocity about any vehicle axis or selecting a surface material with a higher emissivity. An additional, though less effective, method is to design the outer skin to provide maximum thermal conductivity, thus encouraging the greatest possible heat flow from hot to cold spots on the vehicle surface. Of course, any combination of these methods may be used. Analysis of internally produced heat depends upon the specific vehicle configuration. This problem is treated for the sample design of Fig. 2.

Heat Analysis

The calculation methods which follow consider first the general expression and then a sample value calculated for a 300-mile orbit altitude. The emissivity value for the satellite skin is assumed to be 0.4 (conservatively low); the absorptivity is taken as 1.0 (conservatively high). In an actual analysis, appropriate values for these quantities would be used.

Estimate of Earth-Radiated Energy Impinging on Satellite

The earth's surface temperature (average) is assumed to be 14°C., and the average emissivity is taken as 0.5. Therefore the intensity of radiation at the earth's surface is

$$q = E\sigma T_s^4 \tag{1}$$

where

E = emissivity of the earth's surface
σ = Stefan-Boltzmann Constant
T_s = surface temperature, °R.
q = $(0.5)(0.476)(10^{-12})(5.17^4)(10^8)$ = 0.01699 B.t.u./ft.^{2} sec.

However, the radiation intensity varies with cos ϕ, where ϕ is the angle between the local vertical and the sight line to the satellite (see Fig. 1).

If I_0 is the radiation intensity perpendicular to the surface and I_ϕ is the intensity at any angle, ϕ, then

$$I_\phi = I_0 \cos \phi \tag{2}$$

By use of a unit hemisphere placed above the point of radiation, it can be shown that the intensity of radiation passing through any point on the hemispherical surface (at an angle ϕ with the local vertical) is given by

$$q = \int_0^{\pi/2} I_0 \cos \phi \, 2\pi \sin \phi \, d\phi$$

from which

$$I_0 = q/\pi \tag{3}$$

If Q_{rad} is the energy per unit area perpendicular to the satellite local horizontal—i.e., point A—impinging on a 300-mile orbital vehicle, then

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Presented here is a simple way of estimating the maximum and minimum heat inputs experienced anywhere on the outer skin face of an orbiting vehicle. From this rather quickly calculated information, the designer can determine whether he has a reasonable basis for going ahead with a more formal digital computer program, which would take into account the orbit, construction materials, and structural configuration.

$$Q_{rad} = I_0 \int_{-(\pi/2)}^{+(\pi/2)} \int_{0^\circ}^{\theta max} R^2 \cos\phi \cos\alpha \cos\beta \sin\theta \, d\theta \, d\alpha / r^2 \quad (4)$$

(See Fig. 1 for identification of symbols.)

But, since α is integrated from $-(\pi/2)$ to $\pi/2$, the cos integral equals 2, or

$$Q_{rad} = 2I_0 \int_{0^\circ}^{\theta max} R^2 \cos\phi \cos\beta \sin\theta \, d\theta / r^2 \quad (4A)$$

$$\cos\beta = r/\sqrt{r^2 + [(R+h)(1-\cos\theta)]^2}$$

which, if $(R + h)$ is assumed $\approx R$, reduces to

$$\cos\beta \approx \sin\theta/2 \sin(\theta/2) \quad (5)$$

Also,

$$\phi = 180 - \gamma - 90 + \theta$$

where $\gamma = 90 + \text{arc cos}\,[(R \sin\theta)/2]$

$$= 90 + \theta - 90 - \text{arc cos}\,[(R \sin\theta)/2]$$

$$= \theta - \text{arc cos}\,[(R \sin\theta)/2]$$

But, again if $R \approx R + h$, then

$$\phi = 3\theta/2 \quad (6)$$

Combining Eqs. (4A), (5), and (6)

$$Q_{rad} = 2I_0 \int_{0^\circ}^{\theta max} \frac{R^2 [\sin\theta/2 \sin(\theta/2)] \cos(3\theta/2) \sin\theta d\theta}{2R^2(1-\cos\theta)} \quad (7)$$

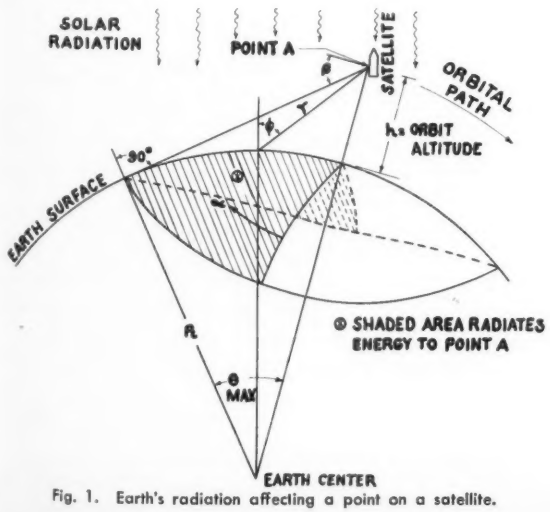

Fig. 1. Earth's radiation affecting a point on a satellite.

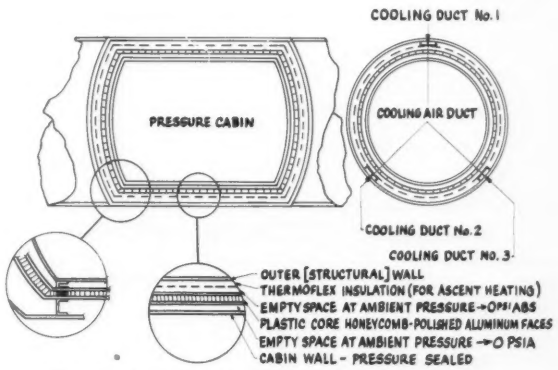
COOLING DUCT No. 1
PRESSURE CABIN
COOLING AIR DUCT
COOLING DUCT No. 2
COOLING DUCT No. 3
OUTER [STRUCTURAL] WALL
THERMOFLEX INSULATION (FOR ASCENT HEATING)
EMPTY SPACE AT AMBIENT PRESSURE → OPS/ABS
PLASTIC CORE HONEYCOMB-POLISHED ALUMINUM FACES
EMPTY SPACE AT AMBIENT PRESSURE → 0 PSIA
CABIN WALL - PRESSURE SEALED

Fig. 2. Nonrecoverable orbital vehicle, sample structure.

Simplification of Eq. (7) yields

$$Q_{rad} = 2I_0 \left[\int_{0^\circ}^{\theta max} 4\cos^5\frac{\theta}{2} \, d\theta - \int_{0^\circ}^{\theta max} 3\cos^3\frac{\theta}{2} \, d\theta \right] \quad (7A)$$

The general solution of Eq. (7A) is

$$Q_{rad} = I_0 \left[3.2\cos^4\frac{\theta_m}{2}\sin\frac{\theta_m}{2} - 0.8\sin\frac{\theta_m}{2} - 0.27\sin^3\frac{\theta_m}{2} \right] \quad (7B)$$

Integrating Eq. (7A) over the indicated limits, $\theta_{max} = 21^\circ$ for a 300-mile orbit

$$Q_{rad} = 2I_0(1.436 - 1.071) = 0.73I_0$$

but from Eq. (3), $I_0 = q/\pi$ so,

$$Q_{rad} = 0.73\, q/\pi = 0.73(0.01699)/\pi = 0.00395 \text{ B.t.u./ft.}^2 \text{ sec.}$$

(energy impinging on point A from the earth's radiation). Note that the energy absorbed by point A = Qa, where a = absorptivity of surface at A.

Estimated Intensity of Reflected Solar Energy Impinging on a Satellite

In this case, the solar energy is reflected in an energy pattern which is hemispherical in shape. To simplify the calculations, the Q is assumed to be analogous to that of Eq. (4).

$$I_0 = q/2\pi$$

but $q \approx 34$ per cent of direct solar radiation[1]

$$\approx 0.34(0.12286)$$

Thus $I_0 = 0.34(0.12286)/2\pi = 0.00665$ B.t.u./ft.^{2} sec.

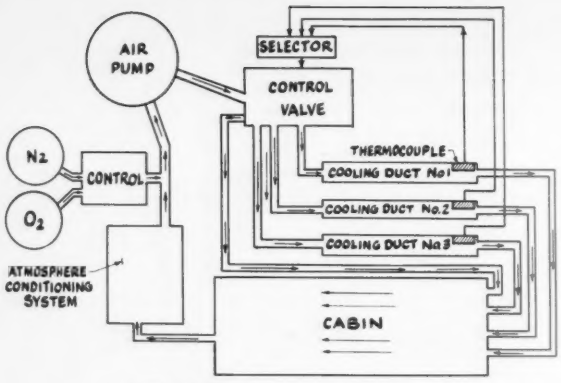

Fig. 3. Temperature control system.

$$Q_{refl} = 2I_0(0.365) = 0.00486 \text{ B.t.u./ft.}^2 \text{ sec. (impinging on satellite)}$$

Note: Encountered only through sun-exposed portion of orbit.

Direct Solar Radiation

The quantity of direct solar radiation absorbed by any point on the satellite is a function of the angle between the sun's rays and the surface and the absorptivity of the surface.

- Q_s = total direct solar radiation absorbed by a unit of area on satellite
- a = absorptivity of satellite surface
- θ = angle between sun's rays and surface
- Q_{sr} = intensity of solar radiation near the earth = 0.1228 B.t.u./ft.^{2} sec.

$$Q_s = aQ_{sr} \sin \theta = 0.1228\, a \sin \theta \text{ B.t.u./ft.}^2 \text{ sec.} \quad (8)$$

Estimate of Outer Wall Temperatures

The methods presented thus far are used to estimate the maximum and minimum temperatures of points on the satellite surface during orbit. These estimates are then used to find the total Q into the surface at a given time and to determine the temperature at which the surface would radiate this energy away

$$Q_{in} = Q_s + Q_{refl} + Q_{rad}$$
$$T_{wall} = (Q_{in}/E\sigma)^{1/4} \quad (9)$$

Evaluation of Thermal Barrier for In-Orbit Insulation on Configuration of Fig. 2

Heat transferred from the cabin walls through the honeycomb reflector to the outer wall is evaluated by the following equation[2]:

$$q = A_1\sigma(T_1^4 - T_2^4)/[(1/E_1) + (A_1/A_2)]\,[(1/E_2) - 1] \quad (10)$$

where

- A_1 = area of outer surface of cabin wall, ft.^{2}
- A_2 = area of inner surface of inner honeycomb face, ft.^{2}
- T_1 = temperature of cabin wall, °R.
- T_2 = temperature of inner honeycomb face, °R.
- E_1 = emissivity of cabin wall outer surface
- E_2 = emissivity of inner honeycomb face (inner surface)
- σ = radiation constant

Based upon the estimates of Eq. (9), wall temperatures of the outer walls are averaged. The cabin wall is assumed constant at 70°F. In this manner, it is demonstrated that the total maximum heat flowing out of the cabin is less than the total heat produced within the cabin. A more exact analysis, utilizing this method and considering the distribution of heat around the outer walls by conduction, is extremely complicated and would require a digital computer program.

Cabin Thermal Control System

Fig. 2 shows a thermal control system in which insulation is used to contain heat, thus eliminating the need for a heater and saving auxiliary power. An air ducting system is used for cooling.

Conductive heat transfer is reduced by the evacuated (ambient) space surrounding the cabin. Both outer faces of the honeycomb shell are highly polished to cut down on transfer by radiation (either inward or outward). Low-conductivity materials and insulating joints are used in all support structures to minimize heat transfer by conduction through the metal joints and supports.

The cooling system has two or more (three are shown in Fig. 3) alternate channels for the air which exhausts from the atmosphere conditioning system. If the cabin is at the desired temperature, all reconditioned air passes directly into the cabin. As the cabin temperature rises above the desired level, the air is directed through the duct which is on the "cold" side of the vehicle at that time. Excess heat in the air is dumped out of the vehicle through the cold outer wall, and the cooled air is then returned to the cabin. Regardless of the orientation or motion of the vehicle, there will be at least one cold surface.

This system lends itself particularly to vehicles which are not rotated relative to any axis of the local horizontal coordinate system—e.g., reconnaissance vehicles which are required to maintain constant position relative to the local horizontal. However, vehicles rotated about their longitudinal axes offer a cold side on either the forward or aft end and so would require only two alternate cooling paths.

The design of a cooling system for a specific vehicle and the applicability of the described cooling system would, of course, depend upon the ratio of outer surface area available to the total amount of heat produced within the vehicle. Such items as the vulnerability of the cooling duct system to meteoritic penetration and the condensation of moisture from the recirculating air on the duct walls are detail design problems which must be solved for each vehicle design.

(*Continued on page 64*)

Potential of Helicopters and VTOL Aircraft

Bartram Kelley, MIAS
Bell Helicopter Corporation

"The helicopter as a concept is very old, but it had to wait for mechanical technology to reach a certain point before it became practical. Further technological advances may soon make other forms of VTOL equally practical."

THE MILITARY establishment has been chief sponsor for the development of VTOL aircraft and the largest user of helicopters to date. At the same time, there is a steadily growing nonmilitary industry covering all parts of the globe and involving itself in a surprisingly large number of economic activities. Because this commercial helicopter business has proved to be firmly established and stable, and because it includes a great variety of activities, it provides the best basis for judging the potential of future VTOL aircraft. I intend to discuss *first* the small utility helicopter, *second*, the large utility and passenger-carrying helicopter, and, *third*, other forms of VTOL now under development.

Commercial Applications

At present there are approximately 650 small utility helicopters in commercial operation in the United States and Canada, doing something between 30 and 50 million dollars worth of business per year. This business is profitable and is not stimulated by any direct or indirect subsidy. The competitors of the small helicopters are almost never airplanes; they are likely to be boats, horses, trucks, buses, or pedestrians. Only in the cases of agricultural work, and power and pipeline patrols, does the airplane sometimes appear as a direct competitor. The chief commercial applications have been in remote parts of the world—oil fields in the Gulf of Mexico or in the Sahara, the mountains of Western Canada, or the jungles of South America. There has also been a growing use of the small helicopter in the United States by law enforcement agencies, radio stations, newspapers, road builders, pipeline and other heavy construction industries, power line patrols, and executive transports.

This paper is slightly revised and condensed from an address by the author before the New Applications of Air Vehicles Session, IAS National Midwestern Meeting on New Frontiers for Aviation, Wichita, Kan., Nov. 2–4, 1959.

Mr. Kelley received his B.A. degree from Harvard in 1933 and M.A. degree from the same University in 1934. In November, 1941, he joined Bell Aircraft Corp. as assistant to Arthur M. Young, designer of the first Bell helicopter. In 1948 he was appointed Chief Engineer of the Helicopter Division and in 1957 became Vice-President—Engineering of Bell Helicopter Corp., the position he now holds. Besides being the author of several technical papers which have been published in various national and international scientific journals, he is a past president of the AHS and a member of the SAE and the Helicopter Assn. of Great Britain. Mr. Kelley has never piloted an airplane, but holds a Commercial Helicopter Pilot's rating and has flown all of the models he has designed.

One large public utility has been patrolling all its power lines exclusively with helicopters for almost 10 years. Before that time, the cost of doing the job on foot was approximately $10 a mile. When the helicopter was first introduced, there was a modest reduction in cost. Now the figure is down to $1.52 a mile as the overall net cost of patrolling the lines by helicopter.

In the heavy construction industry, all forecasts indicate a rapidly increasing potential for the helicopter in the near future. At first, only the high-priority top executives were carried out to inspect jobs in progress. Then, supervisory industrial personnel were carried, and this has led to a multiplicity of daily routine uses never dreamed of previously.

Recently a high-altitude market has opened up. It has been found that the combination of a piston engine with a turbosupercharger is an especially happy one for helicopters and allows profitable operation up to density altitudes well above 20,000 ft. The helicopter replaces teams of men breaking trials and setting up camps for such jobs as mapping, prospecting, mining, all aspects of forestry, and in fact any human activity in mountainous terrain. Recently the valley of the Blue Nile in Ethiopia has been surveyed by helicopter. Operations were carried on at density altitudes between 7,000 and 16,000 ft.

With an expanding world economy and the industrialization of undeveloped areas, this small helicopter industry should continue to flourish and grow to a very large dollar volume. In order to realize the potential, we must look for a reduction in the present vehicle cost, chiefly through a great increase in numbers produced.

Large utility and passenger-carrying helicopters have also made their mark. We are all familiar with the scheduled services available in New York, Chicago,

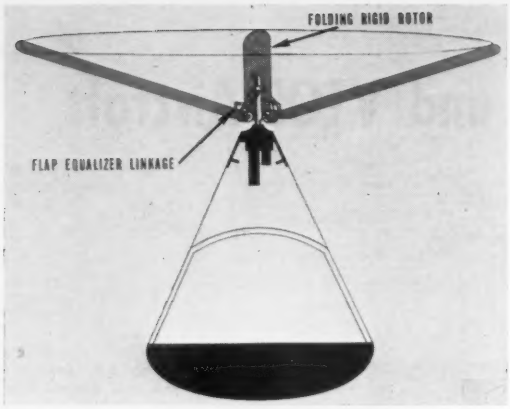

Fig. 1. Rotor landing system for one-man capsule.

Los Angeles, Brussels, Milan, etc. These same larger machines have also been working in the boondocks beside their smaller cousins, and in this role they, too, have no competition from the airplane and do not concern themselves with passenger-seat-mile cost. But when they come into cities to carry people between airports and from the airport to the city center or to suburbs, the story is different, and the passenger-seat-mile cost becomes important. Our three major carriers in New York, Chicago, and Los Angeles are all partially subsidized. As far as the public is concerned, they are extremely successful and thousands of passengers have had to be turned away. The operating record has been most impressive, and there is absolutely no doubt of the potential for a vast expansion. Personally, I see nothing wrong with the present subsidy as such. There is hardly any form of public scheduled transportation which does not operate at a loss, from the lowly subway to the luxury passenger train. The airplane industry would certainly have had a hard time getting started without subsidies, especially if it had been forced to finance its own airports. Cost is not the only criterion for the introduction of improvements in transportation. If it were, we would not have the steam engine or the automobile. With each innovation there is always an increase in cost, which must be weighed against the time-saving and other advantages. If I had come from Dallas to Wichita on the basis of the cheapest passenger-seat-mile, I should have walked or ridden a mule. However, it must be conceded that the vast potential for the short-haul passenger-carrying helicopter cannot be realized until some improvements have been accomplished. In addition to a reduction in cost, there must be a reduction in maintenance requirements, an improvement in instrument flying capability, and a reduction in noise. There are considerably more technical improvements needed than in the case of the small utility machine, but these improvements are all in sight and do not represent large research programs or radical breakthroughs. Again we have a chicken-and-egg situation because the greatest barrier—cost—will be overcome when numbers increase. In Europe we are already witnessing intercity helicopter operation in almost direct competition with airplanes, and in such operations the need for cost reduction is even greater because the helicopter becomes a cross-country bus instead of a local bus or a taxi.

Helicopter Characteristics

Hoverability

Next I would like to discuss some of the characteristics of the helicopter which have contributed to its success. Foremost, of course, is the ability to hover. Now hovering does not merely mean remaining motionless near the ground on a calm day. Hovering implies the ability to fly backwards and sideways at speeds equaling any wind velocities normally to be expected. At first it was thought that the requirement for rearward flight was overemphasized, but worldwide experience has proved that a VTOL must be capable of hovering in gusty winds from any direction if its potential is to be realized. A speed of 30 knots has generally been considered acceptable, and in the case of the helicopter this means the ability to pass through the transition from a hover to flight in any direction.

Table 1. VTOL and V/STOL Research Aircraft Projects, 1950–1958*

(Estimated Total Cost—Over $100,000,000)

Principle of Operation	Rotor	Propeller	Ducted Fan	Turbojet
Dual propulsion	†McDonnell XV-1 (AF-A)			
Thrust tilting	†Bell XV-3 (AF-A) Transcendental (AF-A)	†Vertol 76 (N-A) VZ-2 †Hiller X-18 (AF)	†Doak 16 (A) VZ-4	
Thrust deflection	†Kaman K-16 (N)	Ryan 92 (N-A) VZ-3 Fairchild M-224 (A) VZ-5	Piasecki Ring-Wing (N) Collins Aerodyne (N-A)	†Bell X-14 (AF)
Aircraft tilting:				
Tail sitter		Convair XFV-1 (N) Lockheed XFV-1 (N)		Ryan X-13 (AF)
Flying platform	Delackner Rotocycle (A)		Hiller (N-A)	
Aerial jeep			Aerial jeeps (A) Aerophysics VZ-6 Chrysler VZ-7 Piasecki VZ-8	

* Sponsored by military services, U.S. Department of Defense.
† Article in *AHS Journal*, January, 1959.

Autorotation

A second characteristic is autorotation. Any single-engine VTOL must naturally be able to make a safe descent and landing in the case of power failure. All flight controls must function normally, and the dead stick landing itself must not require extreme pilot proficiency. As in the case of fixed-wing airplanes, multiengine installations can modify this requirement, but it is still necessary to demonstrate varying degrees of partial power failure.

The extent to which autorotation is used in normal helicopter operations is not generally appreciated even in aviation circles. The usual approach to a spot is made with very little or no power and at a steep angle of descent. It would be a distinct handicap to have to approach at cruising speed and treetop level before coming to a hover for the helicopter would lose its invaluable ability to get into and out of tightly confined areas. Good stability and handling characteristics during steep descents have not always been easily achieved and should certainly be considered in evaluating the potential of any future VTOL configurations. Not only can the helicopter pilot descend from cruising altitude very steeply, but he is never committed and can always change his mind and abort any landing except in case of power failure.

Downwash Velocity

Another consideration is that of downwash velocity. The disc loadings of helicopters actually in service have covered a wide range, and already a limit has been reached where excessive downwash velocity has become a severe operational hazard. Yet there is a tendency to ignore the problem when considering new forms of VTOL. A machine which can hover only over a prepared surface will be greatly limited in its potential even if it can fulfill certain specialized missions. For the point of the helicopter is that it can go *anywhere*, and its economy depends on its amazing versatility. If this versatility is reduced, then there must be a corresponding reduction in cost or some other compensating advantage. A VTOL which costs more than a helicopter and has less versatility clearly cannot compete on an economic basis.

A shortcoming of today's helicopters is their comparatively low cruising speed. True, there are many jobs where speed is of only minor importance, but, nevertheless, an increase from today's 100-knot cruise to something in the 170–200-knot range would be highly desirable. Although this is primarily true in military applications, speed also has a strong effect on the seat-mile costs of passenger-carrying machines. Some progress is currently being made, and helicopters cruising faster than 150 knots are beginning to come into sight.

Other VTOL's

Next let us consider VTOL's other than the helicopter. The *Journal of the American Helicopter Society* for January, 1959, was devoted entirely to the subject of VTOL. This issue represents probably the best available summary of the present state of research and is a must for anybody interested in the subject. In particular, the military point of view is ably presented in this magazine by Horton & Klingenhagen. Table 1, which is adapted from Fig. 13 of Horton & Klingenhagen, shows a listing of some recent projects and their principles of operation. In general, as we look from left to right we go in the direction of increasing downwash velocity and decreasing hovering efficiency. This disadvantage must be offset by an increase in cruising speed in order to show a useful potential. For example, if the aerial jeeps cannot reach speeds appreciably higher than the helicopter, their economic future is definitely clouded. (Ground pressure machines are not included because they are outside the scope of our discussion.) Now bearing in mind the flying qualities of the helicopter which have made it commercially successful, we see that in general the machines toward the left side of the chart tend to be more practical than those toward the right. Going from the rotor toward the turbojet, we move in the direction of increased specialization and less general utility, hence less commercial potential. Military potential will depend on the overpowering importance assigned to any one particular mission, and we must leave this mission evaluation to our professional military people.

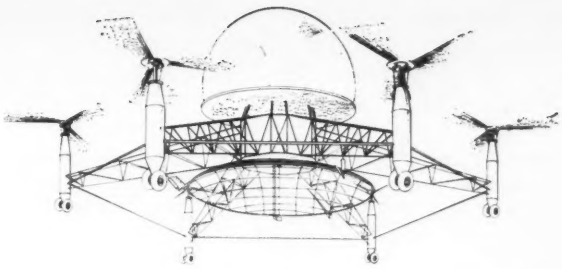

Fig. 2. "Snowflake"—design proposed for the microwave-powered platform system.

In the meantime, it is most important to continue the present intensive researches and test bed evaluations in order to explore all possible means of VTOL. It is equally important to continue work in methods, materials, and power-plant and propulsion devices. The helicopter as a concept is very old, but it had to wait for mechanical technology to reach a certain point before it became practical. Further technological advances may soon make other forms of VTOL equally practical.

I would like to point out one or two examples of highly specialized rotary wing aircraft aimed at specific high-priority missions. It is possible that a rotor could be used for re-entry and landing of a manned satellite capsule (Fig. 1). The autorotating rotor may well provide advantages in dealing with the aerodynamic heating problem encountered during re-entry, and will also allow the pilot to maneuver while selecting his spot

and making a safe landing. A rotor may also be used for recovery of first-stage boosters.

Fig. 2 shows a configuration designed to hover at about 60,000 ft. It has been proposed to generate a vertical beam of electromagnetic energy which would supply power for the helicopter. The purpose would be to support radar antennas and communications equipment at high altitude.

Conclusions

The following points may be stated in summary:

(1) The commercial potential of small helicopters in industrial work is very large and is just beginning to open up.

(2) The potential of larger passenger-carrying helicopters is equally great but slightly further in the future since costs must be reduced and some engineering refinements are needed.

(3) In general utility work the proved flight characteristics of the helicopter must be retained by any VTOL. Control in rearward flight and in steep descents has not been sufficiently emphasized.

(4) The more inefficient forms of VTOL other than the helicopter can be justified only if they are adapted to specific, high-priority missions.

(5) Technological advances such as improvements in the properties of materials will be responsible for the next steps in exploration of the unlimited potential for VTOL.

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Potential of the Air-Cushion Vehicle

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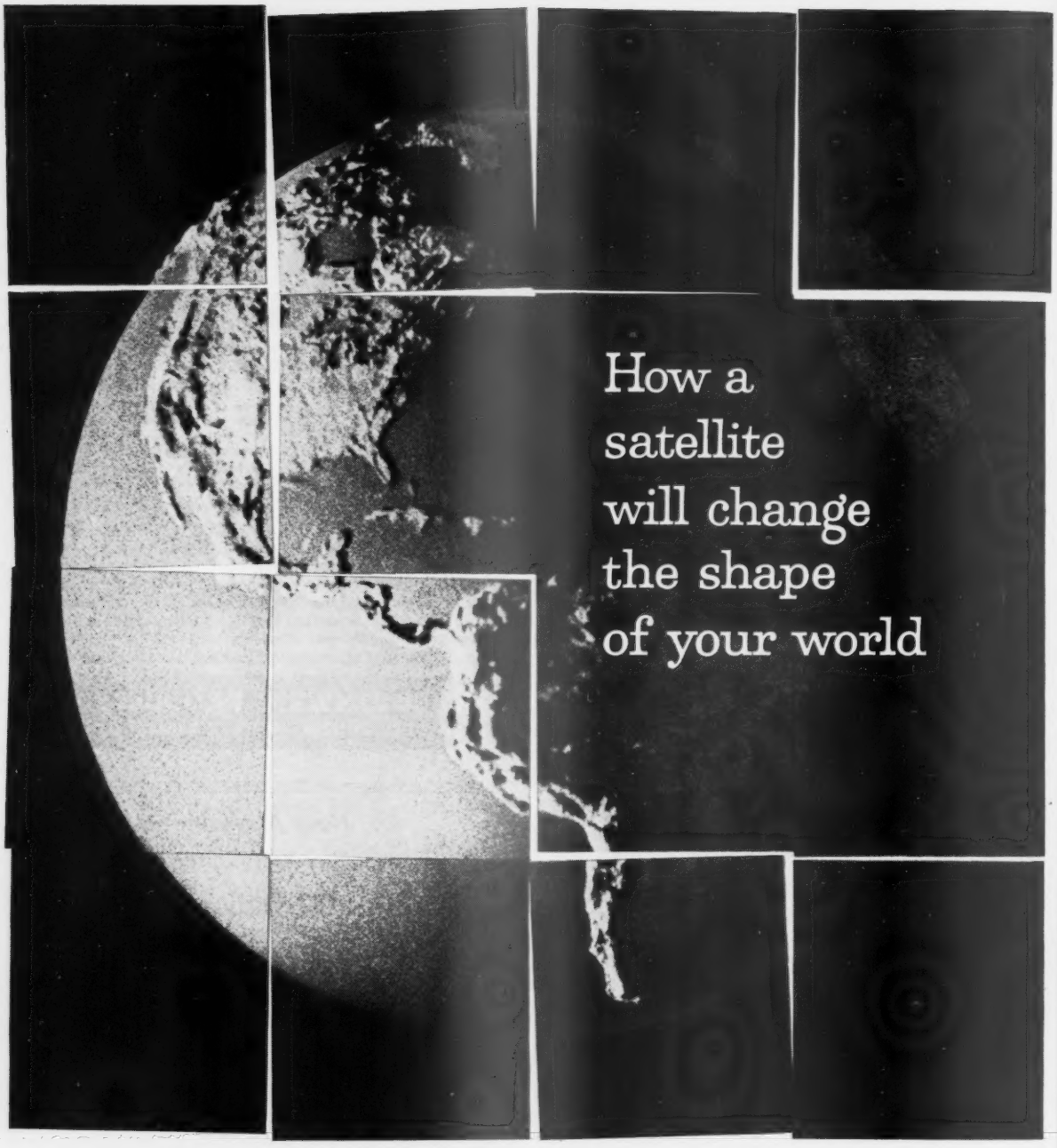

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Acoustics, Sound, Noise

A Summary of Preliminary Investigations Into the Characteristics of Combustion Screech in Ducted Burners. *U.S., NACA Rep. 1384*, 1958. 18 pp. 18 refs. Supt. of Doc., Wash., $0.25. Summarized survey of NACA research prior to 1954 on the screeching combustion problem.

Investigations of Acoustic, Thrust, and Drag Characteristics of Several Jet Noise Suppressors. E. E. Callaghan. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 57R.* 6 pp.

Effect of Forward Velocity on Sound-Pressure Level in the Near Noise Field of a Moving Jet. J. C. Fakan and H. R. Mull. *U.S., NASA TN D-61*, Oct., 1959. 16 pp. Presentation of the results of an in-flight investigation conducted over a flight Mach number range of 0.35 to 0.70 at altitudes of 10,000, 20,000, and 30,000 ft., at 2 and 3 nozzle-exit diameters downstream of the jet exit. The sound pressure levels are found to be constant over the full Mach number range.

Measurements of Free-Space Oscillating Pressures Near Propellers at Flight Mach Numbers to 0.72. M. C. Kurbjun and A. W. Vogeley. *U.S., NACA Rep. 1377*, 1958. 9 pp. Supt. of Doc., Wash., $0.20.

Experience of Supersonic Flying Over Land in the United Kingdom. T. H. Kerr. *Gt. Brit., RAE TN Aero. 2642*, Aug., 1959. 17 pp. Assessment of the effects of low-level supersonic flying over populated areas. Some measurements from the ground of bang intensities are presented.

Aerodynamics, Fluid Mechanics

Aerothermochemistry, Dissociation, Ablation

The Stagnation-Point Ablation of Teflon During Hypersonic Flight. S. M. Scala and N. S. Diaconis. *J. Aero/Space Sci.*, Feb., 1960, pp. 140, 141. USAF-sponsored comparison of theoretical and experimental work on the ablation of Teflon indicating that extensive care must be used in analyzing the effects of the mass transfer of chemically reacting species whose molecular weight differs appreciably from that of air molecules.

Aerothermodynamics

A Note on the Approximate Calculation of the Temperature Distribution in an Incompressible Laminar Boundary Layer Over a Heated Plane Surface. D. E. Bourne. *Quart. J. Mech. & Appl. Math.*, Aug., 1959, pp. 337–339.

The Effect of Shock-Generated Vorticity, Surface Slip, and Temperature Jump on Stagnation-Point Heat-Transfer Rates. H. Hoshizaki. *J. Aero/Space Sci.*, Feb., 1960, pp. 135, 136.

Heat Conduction in Solids at Hypersonic Speeds. L. Broglio. (*NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 209*, Oct., 1958. 16 pp. Extension of a general approach used previously for heat conduction problems to a body whose thermal properties are dependent upon temperature. The case of hypersonic flight is considered, and a numerical application is made to a hollow steel hemisphere at hypersonic speed.

Heat Transfer at a Corner. Victor Zakkay. *J. Aero/Space Sci.*, Feb., 1960, pp. 157, 158. USAF-supported comparison of theoretical and experimental results for heat transfer over a blunt body, and evaluation of errors caused by flow around the corner in the analytical methods.

Periodic Temperature Distribution in a Two-Layer Composite Slab. T. E. Stonecypher. *J. Aero/Space Sci.*, Feb., 1960, pp. 152, 153. Partial solution of temperature distribution equations of a slab assuming that one exposed surface of the slab is adiabatic and the other exposed surface is subjected to sinusoidal temperature variation.

Considerations in the Application of Evaporative Cooling Systems to Hypersonic Vehicles. Eli Kaplan. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 54T.* 9 pp. Analysis of two different problems: the optimum insulation for an evaporatively cooled space; and choking in ducts with friction and heat transfer.

Boundary Layer

Skin Friction Measurements During Ascending Viking Flight. F. W. Fenter and W. C. Lyons, Jr. (*Quart. Rev. Bumblebee Activ.*, Jan.-Dec., 1958.) *Johns Hopkins U. APL BB Rep. 283*, 1959, pp. 5–13. Comparison of test results, using acceleration-insensitive skin friction balances at stations near the nose and tail of the rocket, with theoretical calculations.

Static Tests of an External-Flow Jet-Augmented Flap Test Bed with a Turbojet Engine. M. P. Fink. *U.S., NASA TN D-124*, Dec., 1959. 19 pp. Presentation of test results for several tailpipes with various width-height ratios and having a flap-slot gap varying through a range of heights for several entrance ramp angles.

Boundary-Layer Transition on Blunt Bodies with Highly Cooled Boundary Layers. K. E. Stetson. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Rep. 59-36.*) *J. Aero/Space Sci.*, Feb., 1960, pp. 81–91. 20 refs. USAF-sponsored research.

The Calculation of the Compressible Turbulent Boundary Layer in an Arbitrary Pressure Gradient—A Correlation of Certain Previous Methods. B. S. Stratford and G. S. Beavers. *Gt. Brit., NGTE Memo. M.330*, Sept., 1959. 22 pp. 17 refs. Presentation of a correlation equation for the methods of Tucker, Young, Englert, Mager, and Reshotko and Tucker.

The Determination of the Local Skin Friction and the Thickness of Turbulent Boundary Layers from the Velocity Similarity Laws. P. S. Granville. *U.S., Navy Dept., David Taylor Model Basin Rep. 1340*, Oct., 1959. 16 pp. 22 refs. Discussion of the application of pipe calibrations of Preston tubes to boundary layers on the basis of the logarithmic similarity law and the displacement effect of the tubes. A new logarithmic formula especially useful for high Reynolds numbers is also derived from the similarity laws.

Control Surfaces

A Limited Flight and Wind-Tunnel Investigation of Paddle Spoilers as Lateral Controls. R. G. Mungall, H. I. Johnson, and W. L. Alford. *U.S., NASA TN D-32*, Sept., 1959. 20 pp. Presentation of flight test results obtained on a swept-back wing fighter aircraft and wind-tunnel measurements on a semispan wing model. Data on the rolling effectiveness and the hinge moment characteristics of the paddle spoilers at various subsonic speeds are presented.

Investigation at Transonic Speeds to Determine Lateral Control Effectiveness of Blowing Laterally Over Surfaces of 30° and 45° Swept Wings. A. D. Hammond and L. W. McKinney. *U.S., NASA TN D-42*, Oct., 1959. 53 pp. Description of wind-tunnel tests on wings equipped with a nozzle located near the trailing edge of the root chord so that a jet of high-pressure air could be directed across the wing toward the wing tips at various sweep angles. The basic data are presented in tabular form, and the partial derivatives of the force and moment coefficients with respect to momentum coefficient are given in graphical form.

The Effects of an Inverse-Taper Leading-Edge Flap on the Aerodynamic Loading Characteristics of a 45° Sweptback Wing at Mach Numbers to 0.90. F. A. Demele. *U.S., NASA TN D-138*, Dec., 1959. 108 pp. Investigation to determine the wing-surface pressures and aerodynamic loading associated with deflection of an inverse-taper leading-edge flap on a swept wing-body combination. Data are presented for flap angles to 16° at Mach numbers of 0.60 to 0.90 with a Reynolds number of 3.2 million, and at a Mach number of 0.25 with a Reynolds number of 15.0 million.

Flow of Fluids

Theory of Oscillation of a Viscoelastic Medium Between Parallel Planes. G. B. Thurston. *J. Appl. Phys.*, Dec., 1959, pp. 1855–1860. 14 refs. Presentation of a theory for sinusoidal oscillation of an incompressible viscoelastic medium between fixed infinite parallel planes. The mechanical properties of the viscoelastic medium under sinusoidal shear are expressed by a complex viscosity coefficient. Functions from which the acoustic resistance and acoustic reactance may be determined are presented in graphical form for media which range from a perfect viscous fluid to a perfect elastic solid.

The Hydraulic Analogy for External Flow. R. A. A. Bryant. *J. Aero/Space Sci.*, Feb., 1960, pp. 148, 149. Presentation of a two-dimensional analogy – flow in a channel having a horizontal bottom. No restriction is placed on vorticity in the analogy. Consequently, for rotational flows the analogous prediction equations can be applied along corresponding streamlines as long as the two flows are kinematically similar.

An Exact Calculation of Some Steady, Diabatic, Two-Dimensional Fields of Compressible Flow. B. L. Hicks and D. R. Chenoweth. *J. Aero/Space Sci.*, Feb., 1960, pp. 142–144.

Research on Experimental Investigation of Variable Circulation Around an Aspirated Cylinder. *Inst. Rech. Sci. & Tech. Centre-Ouest Rep. EI/573* (*AFOSR TR 59-105*) [*AD 162109*], 1959. 37 pp. Investigation to determine the conditions necessary to obtain maximum lift and lift-drag ratio for a porous cylinder arranged to permit the aspiration of the surface laminar sublayer.

A Simple Numerical Solution of the Supersonic Blunt-Body Problem for Real Gases. G. A. Bird. *J. Aero/Space Sci.*, Feb., 1960, pp. 151, 152. Presentation of a solution obtained by a step-by-step method making use of only elementary forms of the equations of motion and which may, therefore, be based on realistic assumptions about the thermodynamic processes.

Bodies of Rotation Having Minimal Resistance at Supersonic Velocities. Yu. D. Shmyglevskii. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 541–543. Translation. Analysis of the problem of finding a contour such that the wave resistance is minimal for a given speed at infinity.

Comparison of Theoretical and Measured Surface Pressures at M = 1.2 on Three Bodies Having Different Waistings. W. R. Buckingham. *Gt. Brit., RAE TN Aero. 2638*, July, 1959. 12 pp.

Experiments on the Flow Past a Circular Cylinder at Low Reynolds Numbers. D. J. Tritton. *J. Fluid Mech.*, Nov., 1959, pp. 547–567. 30 refs. Presentation of measurements of the drag on circular cylinders in a stream with the Reynolds number range of 0.5 to 100. Comparisons are made with experimental values and with various theoretical calculations. Experiments are described for the transition in the mode of the vortex street in the wake of a cylinder at a Reynolds number of about 90. The nature of this transition and the differences between the flows on either side of it are described.

The Effect of Unsteadiness on Hydrodynamic Resistances and on Mass Oscillations in Surge Tanks. Turgut Sarpkaya. *Eng. Inst. Canada Trans.*, Nov., 1959, pp. 96–99. 10 refs.

Shape-Preserving, Exact Solutions of the Equations of Magnetohydrodynamics. N. N. Kochina. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 521–525. Translation.

Some Exact Solutions of the Equations of Magneto-Gas Dynamics with Internal Gravitational Forces Present and with a Zero Temperature Gradient. E. V. Ryazanov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 554–557. Translation.

Stationary Flow of an Ideally Conducting Gas Around a Corner. G. A. Lyubimov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 529–531. Translation. Analysis of the flow of an infinitely conducting gas around a corner having an arbitrary external magnetic-field distribution relative to the flow.

On the Phenomenon of Magnetic "Detachment" of the Flow of a Conducting Medium. V. N. Zhigulev. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 514–516. Translation. Analysis of the flow of a conducting gas around bodies having a magnetic field of their own. The problem is developed and a method of solution is given for phase problems associated with the phenomenon of detachment of the flow of a conducting medium at large Reynolds numbers. An example of the hypersonic flow of gas around a current filament is examined.

The Use of Magnetic Probes in Plasma Diagnostics. R. H. Lovberg. *Ann. Phys.*, Nov., 1959, pp. 311–324. 23 refs. Study of the technique of magnetic probing of magnetohydrodynamic systems in relation to other diagnostic means. Procedures for extracting plasma data from magnetic field plots are outlined together with specific examples.

The Effects of Electrode Contamination on the Properties of Air-Arc Plasmas. H. Y. Wachman, M. J. Linevsky, and J. H. McGinn. *G-E MSVD AL TIS R59SD427*, Sept. 21, 1959. 25 pp.

On the Approximation Method in Investigation of Plane Rotational Flow in Magnetohydrodynamics. I. I. Nochevkina. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 549–553. Translation.

Electro-Hydromagnetic Waves in a Fully Ionized Gas. I. K. D. Cole. *Planetary & Space Sci.*, Sept., 1959, pp. 319–324. 13 refs. Application of the transport equations to determine coefficients that are generalizations for any frequency of electric field of the parallel, Pedersen, and Hall conductivities in a fully ionized gas. The coefficients are used in an investigation of the propagation of weak electromagnetic and hydromagnetic waves of all frequencies across a homogeneous and constant magnetic field in a rarefied, fully ionized gas.

On the Calculation of Shock Waves in Magnetohydrodynamics. M. I. Kiselev. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 517–520. Translation. Presentation of a method for simplifying the calculations of the parameters of the medium behind the wave front by reducing the power of the equation by one.

Shock Waves with Discontinuous Gas Conductivity Situated in an Electromagnetic Field. G. A. Lyubimov. *Sov Phys. - Dokl.*, Dec., 1959, pp. 510–513. Translation.

Flexure of a Two-Dimensional Arc Under Forced Convection. P. G. Thiene. *Plasmadyne Corp. TN T 2TN089-334* (*AFOSR TN 59-947*), Aug. 25, 1959. 83 pp. Analysis of the nature of the physical mechanism which maintains an arc in the presence of forced convection. An analogy is qualitatively drawn between the convection-loaded arc model and a structural beam with a distributed load.

An Experimental Study of Spark Stabilization by a Gas Vortex. Christopher Cobb and V. H. Blackman. *Plasmadyne Corp. TN T 3TN099-334* (*AFOSR TN 59-925*), Aug. 28, 1959. 32 pp. Investigation of the discharge of sparks along the axis of a vortex by a time-resolved photographic study.

Sound Pulses in a Conducting Medium. F. G. Friedlander. *Cambridge Philos. Soc. Proc.*, Oct., 1959, pp. 341–367. Analysis of the propagation of small disturbances in a compressible fluid which is also a conductor of electricity, in the presence of a magnetic field. The characteristic feature of the problem is that it combines

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sound waves and magnetohydrodynamic waves. The theory is based on linearized equations which generalize the equations of motion of the theory of sound. Energy dissipation by viscosity, heat conduction, and Joule heat is neglected, and so is the displacement current.

Propagation Characteristics of Detonation-Generated Plasmas. M. A. Cook, R. T. Keyes, and L. L. Udy. *J. Appl. Phys.*, Dec., 1959, pp. 1881–1892. 11 refs. USAF-supported presentation of studies showing the electrical properties of highly ionized, detonation-generated plasmas ejected into various gaseous media at the base surfaces of high explosives.

On Magnetohydrodynamic Channel Flow. J. E. McCune and W. R. Sears. *J. Aero/Space Sci.*, Feb., 1960, pp. 139, 140. Examination and clarification of previous papers by Resler and Sears on the subject of channel flow.

Similar Solutions for Boundary Layers in Constant-Temperature Magneto-Gasdynamic Channel Flow. J. L. Kerrebrock. *J. Aero/Space Sci.*, Feb., 1960, pp. 156, 157.

Electric Propulsion—Measurements with a Small Thrust Plasma Generator. B. Gorowitz and B. W. Harned. *SAE Natl. Aero. Meeting, New York, Mar. 31-Apr. 3, 1959, Preprint 63T.* 18 pp. 14 refs. Measurements of velocity and momentum of plasma bursts, both in single-shot and pulsed operation over a range of pressures and input energies for various magnitudes and directions of magnetic field at the gaseous discharge.

Motions with Initial Gradient. I. Gheorghitza. *Quart. J. Mech. & Appl. Math.*, Aug., 1959, pp. 280–286. Analysis of the motion of incompressible fluids in a porous medium when the modulus of the gradient of the dynamic pressure surpasses a given value.

Slow Rotatory Motion of a Circular Disk About One of Its Diameters in a Viscous Fluid. R. P. Kanwal. (*ASME West Coast Conf., Stanford, Sept. 9–11, 1959, Paper 59—APMW-6.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 485–487. 10 refs. Army-sponsored presentation of an analytical solution for the case of a rigid circular plate rotating about a diameter in its plane and placed in an infinite mass of viscous fluid. Formulas are derived for the velocity components, pressure, and couple experienced by the disc.

Propagation of Weak Disturbances in a Gas Subject to Relaxation Effects. F. K. Moore and W. E. Gibson. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Rep. 59-64.*) *J. Aero/Space Sci.*, Feb., 1960, pp. 117–127. 15 refs. USAF-supported research.

Exact Solutions for the Propagation of Explosion Waves in a Gravitating Gas with Zero Temperature Gradient. E. V. Ryazanov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 537–540. Translation.

On Particularities Near the Detonation Center and on the Appearance of Two Shock Waves. N. N. Kochina. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 544–548. Translation. Analysis of the problem of point detonation in a compressible medium.

The Effect of an Electromagnetic Field on the Detonation Regime. G. A. Lyubimov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 526–528. Translation. Analysis taking into account the fact that after the passage of the detonation wave the gas becomes conducting.

A Graphical Solution for Normal Shock Waves in Real Gases. Ch. E. Treanor. *J. Aero/Space Sci.*, Feb., 1960, pp. 158–160. USAF-supported study.

An Example of Plane-Parallel Transonic Flow with a Curved Density Step Terminating Within the Flow and Having a Stream Function. I. Biibosunov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 532–536. Translation.

On the Development of a Vortex Street in a Free Convection Boundary Layer. Tetsu Fujii. *JSME Bul.*, Nov., 1959, pp. 551–555. Measurement in free convection boundary layers for ethyleneglycol or water along a vertical cylinder. At the point of the transition from a laminar layer to a vortex street layer, the number of the vortices developed per unit-time and their pitch in the vortex street are measured.

On the Structure of Vortical Layers in Supersonic and Hypersonic Flows. H. K. Cheng. (*Cornell Aero. Lab. Rep.*, Oct., 1959.) *J. Aero/Space Sci.*, Feb., 1960, pp. 155, 156.

Symmetric Vortex Separation on Circular Cylinders and Cones. A. E. Bryson. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59–APM-13.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 643–648. 14 refs. Application of the lumped vorticity approximation suggested by Edwards and Hill to analyze the symmetric vortex separation observed on the leeward side of slender bodies of revolution at high angles of attack in the subsonic to moderately supersonic range. The equivalent unsteady two-dimensional problem of indicial motion of a cylinder in an incompressible fluid with symmetrical vortex wake is also considered.

Internal Flow

Application of Boundary-Layer Theory in Turbomachinery. H. Schlichting. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958.*) *ASME Trans., Ser. D - BE*, Dec., 1959, pp. 543–551. 26 refs. Presentation of a method to calculate the aerodynamic coefficients of cascades, and application of these results to the theory of turbomachines.

Résumé of the Supersonic-Compressor Research at NACA Lewis Laboratory. W. W. Wilcox, E. R. Tysl, and M. J. Hartmann. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958, Paper 58–A-177.*) *ASME Trans., Ser. D - BE*, Dec., 1959, pp. 559–568. 35 refs. Review of the development program discussing the objectives and results of the various experiments and associated analyses.

Radial Equilibrium in Supersonic Compressors A. G. Hammitt and S. M. Bogdonoff. (*ASME Annual Meeting, New York, Nov 30–Dec. 5, 1958, Paper 58–A-110.*) *ASME Trans., Ser. D - BE*, Dec., 1959, pp. 552–558. Analysis showing that radial equilibrium through shock waves in both rotors and stators of supersonic compressors is possible for both oblique and normal shocks. The most restricted case for which equilibrium is possible in a stator is a normal shock with variable total head or an oblique shock with variable shock angle.

Sulla Determinazione dei Triangoli di Velocità e del Calettamento delle Pale Rotoriche in un Compressore Assiale Munito di Rotore con Pale Orientabili. Oreste Acton. *L'Aerotecnica*, Aug., 1959, pp. 120–125. In Italian. Determination of velocity triangles and pitch angles of rotor blades in an axial compressor with constant angular velocity. Previously derived results are used to calculate the theoretical blade angles corresponding to different values of the mass flow.

The Normal Rule of "Leading and Lagging Vectors" and Deviations from This Rule in an Axial Turbomachine Stage. V. T. Yourinsky and R. G. Narayanamurthi. *Indian Inst. Sci. J., Sect. B*, July, 1959, pp. 17–22.

Effects of Fluid Viscosity on the Flow in the Impeller of Centrifugal Type Hydraulic Machinery. Goro Kamimoto, Yoshihiro Matsuoka, and Hideo Shirai. *JSME Bul.*, Nov., 1959, pp. 624–629.

Theory of Centrifugal Type Impeller with Vanes of Arbitrary Form. Goro Kamimoto and Yoshihiro Matsuoka. *JSME Bul.*, Nov., 1959, pp. 630–637. 14 refs. Presentation of a method of conformal mapping, based on the mapping function, which maps an impeller with logarithmic spiral vanes into a unit circle. The calculated results are compared with the experimental ones for impellers with three types of vanes.

Investigation of the Effect of a Guide-Vane-Rotor Combination on Inlet Total-Pressure Distortions in a Compressible Fluid. G. C. Ashby, Jr. *U.S., NASA TN D-123*, Dec., 1959. 15 pp. Investigation to determine the effectiveness of having a 90° included angle between the absolute- and relative-flow directions at the inlet of a compressor in reducing an inlet total-pressure distortion.

Gas Flow with Straight Transition Line. L. V. Ovsiannikov. (*Prikl. Mat. i Mekh.*, 1949, pp. 537–542.) *U.S., NACA TM 1295*, May, 1951. 13 pp. Translation. Analysis of a gas flow when the constant pressure in the surrounding medium is exactly equal to the critical pressure for a given initial state of the gas. For a jet flowing out of the opening of a vessel with plane walls, it is shown that equalization of the flow in the jet is attained at a finite distance from the start of the free jet, the line of transition being a straight line.

An Approximation for Subsonic Flow Through an Orifice. P. G. Morgan. *J. Aero/Space Sci.*, Feb., 1960, p. 160.

The Effect of Density on Jet Flow at Subsonic Speeds. A. H. Craven. *Coll. of Aeronautics, Cranfield, Rep. 120*, July, 1959. 20 pp. Analysis based on the assumption that the velocity and density distributions across a jet of one gas issuing into a stream of a second gas are of exponential form. The momentum integral approach is used to find the variation of centerline velocity downstream of the potential core.

Über die Auslegung zweistufiger Heisswasserejektoren. Otto Lutz and Egbert Riester. *ZFW*, Dec., 1959, pp. 350–355. 10 refs. In German. Discussion of two-stage hot water ejectors, covering the mass flow for which the second ejector has to be designed and the extent to which the mass flow and the dimensions of this ejector could possibly be reduced by means of cold water injection.

On an Exact Solution of Laminar Mixing of Two Different Gases. L. G. Napolitano. (*U. Naples Inst. Aero. TN 1, I.A. Rep. 10*, Apr., 1959.) *J. Aero/Space Sci.*, Feb., 1960, pp. 144, 145.

The Critical Pressure Ratio for a Series of Steam or Gas Discharging Orifices and Its Effect on the Maximum Discharge of the System. R. Szewalski. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No. 9, 1959, pp. 541–546.

Untersuchungen und Beobachtungen über die Arbeitsweise von Axialpumpen unter besonderer Berücksichtigung des Teillastbereiches. Wolfgang Scheer. *BWK*, Nov. 5, 1959, pp. 503–511. 15 refs. In German. Investigation of the performance of axial pumps, covering the effect of pump design on stall phenomena and the influence on part-load behavior of such parameters as the number of blades, blade twist, and shape of the hub. The study is also extended to arrangements with radial guide vanes ahead of the impeller.

Jet Flaps & Wings

Large-Scale Wind-Tunnel Tests of an Airplane Model with an Unswept, Aspect-Ratio-10 Wing, Four Propellers, and Blowing Flaps. J. A. Weiberg and V. R. Page. *U.S., NASA TN D-25*, Sept., 1959. 39 pp. Comparison of the results of tests on a model with two propellers with those obtained for four propellers, showing that the lift increment due to thrust is proportional to the slipstream velocity and, for a given thrust coefficient, proportional to the wing area in the slipstream. The drag for a given thrust coefficient and the blowing momentum coefficient for flow attachment on the flap are relatively unaffected by the number of propellers.

Performance

Flight Investigation of the Lift and Drag Characteristics of a Swept-Wing, Multijet, Transport-Type Airplane. Ronald Tambor. *U.S., NASA TN D-30*, Nov., 1959. 27 pp. Presentation of experimental results obtained over the Mach number range from 0.70 to 0.86 for the clean configuration at an altitude of 26,000 ft. Data are also obtained over the speed range of 130 knots to 160 knots at 9,000 ft. for various flap deflections with gear down.

Consideration of Some Aerodynamic Characteristics During Take-Off and Landing of Jet Airplanes. J. M. Riebe. *U.S., NASA TN D-19*, Sept., 1959. 11 pp. Study limited to lift-drag relations excluding such possible related factors as noise, heating, foreign matter ingestion, or ability to obtain thrust reversal. Results of wind-tunnel tests are presented along with implications from the lift-drag effects in relation to differences in operating techniques of jet and propeller-driven transport aircraft.

Low Speed Tunnel Measurements of the Ground Effect on a 1/5th Scale Model of the Swift. M. N. Wood and W. J. G. Trebble. *Gt. Brit., ARC CP 458* (May, 1957) 1959. 54 pp. BIS, New York, $1.35. Presentation of lift, drag, and pitching moment measurements for a model in a free stream, as well as at two distances from a ground board. It is shown that existing theories on ground effect for unswept wings give good estimates of the decrease in induced drag, but underestimate the gain in lift curve slope and overestimate the effect of the ground on the downwash at the tailplane.

Stability & Control

An Exploratory Investigation in a Ballistic Range of the Stability Derivatives of a Simple Airplane Configuration at Low Supersonic Speeds. Ch. E. DeRose and A. G. Boissevain. *U.S., NASA TN D-139*, Dec., 1959. 25 pp. Description of tests on models having two planes of mirror symmetry in a seven station ballistic range at Mach numbers of 1.2 to 1.4 and Reynolds numbers of 0.8×10^6 to 1.0×10^6, based on wing chord.

Analytical Investigation of Effect of Spin Entry Technique on Spin and Recovery Characteristics for 60° Delta-Wing Airplane. S. H. Scher, E. L. Anglin, and G. F. Lawrence. *U.S., NASA TN D-156*, Dec., 1959. 52 pp. Description of a high-speed digital computer study made to investigate the effects of differences in full-scale aircraft and spin tunnel model testing techniques on spins and recoveries. Results indicate that proper evaluation of full-scale spin-recovery characteristics of modern designs from spin-tunnel tests requires cognizance of both tunnel technique and Reynolds number.

An Analysis of Incremental Horizontal-Tail Loads Measured on a Swept-Wing Bomber Airplane in Sideslip Maneuvers. W. A. McGowan. *U.S., NASA TN D-100*, Oct., 1959. 34 pp. Presentation of the results of an analysis covering in-flight measurement during rudder-step, aileron-roll, and steady-sideslip maneuvers. Data were reduced to give derivatives of the horizontal-tail normal force and rolling moment coefficients with respect to sideslip angle and the rate of change of wing-fuselage combination pitching-moment coefficient with sideslip angle.

Moving-Cockpit Simulator Investigation of the Minimum Tolerable Longitudinal Maneuvering Stability. B. P. Brown and H. I. Johnson. *U.S., NASA TN D-26*, Sept., 1959. 46 pp. Description of tests on a normal acceleration and pitch simulator, including measurements of the effects of force gradient, position gradient, aircraft damping, and pitching motion cues with respect to a formation flying task.

Jet Effects on Longitudinal Trim of an Airplane Configuration Measured at Mach Numbers Between 1.2 and 1.8. R. F. Peck. *U.S., NASA TN D-177*, Dec., 1959. 17 pp. Presentation of test results indicating that the model encountered large jet-induced effects on longitudinal trim between Mach numbers of 1.2 and 1.8. These effects are believed to have resulted from the fact that the horizontal tail either intersected or was

very close behind a shock wave in the external flow originating near the intesection of the external flow and the jet boundary.

Wings & Airfoils

Alcuni Problemi dell'Aerodinamica di Profili in Correnti Non Uniformi. I—Problema Piano. Enrico Pistolesi and Marino Marini. *L'Aerotecnica*, Aug., 1959, pp. 101–119. In Italian. EOARDC-sponsored investigation of the behavior of an airfoil in nonuniform flow. The effects of flow nonuniformity are calculated for (a) the lift of an airfoil of zero thickness at small incidence and (b) the velocities on a thick airfoil at zero incidence.

Calculation of the Load Distribution Over a Wing with Arbitrary Camber and Twist at Sonic Speed. K. W. Mangler and D. G. Randall. *Gt. Brit., ARC R&M 3102* (Jan., 1955) 1959. 46 pp. BIS, New York, $2.88. Development of a method for the calculation of the pressure distribution over a wing with arbitrary camber and twist at sonic speed. The results are also valid for wings of small aspect ratio at any Mach number.

A Theory of the Separated Flow from the Curved Leading Edge of a Slender Wing. J. H. S. Smith. *Gt. Brit., ARC R&M 3116* (Nov., 1957) 1959. 18 pp. BIS, New York, $1.17. Extension of the simple model used by Brown and Michael to represent the flow past a slender delta wing with leading edge separation to the cases of wings having pointed apexes, curved leading edges, and straight, unswept trailing edges.

La Portanza e la Resistenza dell'Ala Infinita in Relazione ai Teoremi della Quantità di Moto e dell'Energia. Dante Cunsolo. *L'Aerotecnica*, Aug., 1959, pp. 126–132. In Italian. Study covering the lift and drag of an infinite wing considered in terms of the momentum and energy theorems. The kinetic energy is calculated for the case of elliptical lift distribution, showing good agreement with results obtained for the induced drag.

The Transonic and Supersonic Area Rule. R. T. Whitcomb. (*Rhode-Saint-Genèse, Belgium, Lectures, Feb., 1958.*) *TCEA TM 1*, Jan., 1958. 49 pp. 17 refs. Discussion of the physical bases, development, application, and limitations of the basic rule and its extensions.

Drag Minimization for Wings and Bodies in Supersonic Flow. M. A. Heaslet and F. B. Fuller. *U.S., NACA Rep. 1385*, 1958. 18 pp. 16 refs. Supt. of Doc., Wash., $0.25. Study of the minimization of inviscid fluid drag for aerodynamic shapes satisfying the conditions of linearized theory, and subject to imposed constraints on lift, pitching moment, base area, or volume.

Flight Measurements of the Drag of an Aircraft Fitted with a Rear Fuselage Fairing Designed to Reduce the Transonic Drag. D. R. Andrews, F. W. Dee, and D. Waters. *Gt. Brit., ARC CP 459* (Nov., 1956) 1959. 19 pp. BIS, New York, $0.54. Presentation of test results for a fairing fitted to a Hawker Hunter aircraft, designed to control the shock wave movements in the wing body junction and so reduce the transonic rise.

Aeroelasticity

Research on Aeroelasticity. Luigi Broglio. *Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 51 (AFOSR TN 59-134)*, May, 1959. 16 pp. Summary of results for the following investigations: modeling technique and theory for aeroelastic similarity in blowdown wind tunnel tests, and development of exact solutions for the problem of heat conduction in heterogeneous solids with boundary conditions as a function of space and time.

The Influence of Panel Deformations on Wing Flutter. D. J. Johns. *J. Aero/Space Sci.*, Feb., 1960, pp. 137, 138.

A Simplified Expression for the Period of Nonlinear Oscillations of Curved and Flat Panels. J. E. Greenspon. *J. Aero/Space Sci.*, Feb., 1960, pp. 138, 139.

Atmospheric Turbulence Encountered by Viscount Aircraft Over Europe. J. R. Heath-Smith. *Gt. Brit., RAE TN Struc. 267*, July, 1959. 25 pp.

Application of Power Spectral Methods in Airplane and Missile Design. K. R. Thorson and Q. R. Bohne. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Rep. 59-42.*) *J. Aero/Space Sci.*, Feb., 1960, pp. 107–116. 16 refs.

Interpretation and Applicability of Results of Wind-Tunnel Flutter and Control Surface Buzz Investigations. A. G. Rainey. (*NATO AGARD 14th Wind-Tunnel & Model-Testing Panel Meeting, Copenhagen, Oct. 20, 21, 1958.*) *NATO AGARD Rep. 219*, Oct., 1958. 18 pp. 20 refs.

Random Vibration. S. H. Crandall. *Appl. Mech. Rev.*, Nov., 1959, pp. 739–742. 114 refs. Survey of the literature on random vibrations including general theory, sources of random excitation, responses of vibratory systems to random excitation, failure due to random vibration, and design and test problems.

Stability of Forced Oscillations with Nonlinear Second-Order Terms. Chi-Neng Shen. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59—A-19.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 499–502. Derivation of a solution for forced oscillations, using both the perturbation and continued fraction methods to analyze the boundary of stability. The amplitude of oscillation with damping terms is also determined by the iteration procedure.

Forced Vibrations of a Circular Plate. Herbert Reismann. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59—A-9.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 526, 527. Presentation of a solution for the response of a clamped circular plate to the action of an arbitrarily placed, harmonically oscillating, transverse, concentrated force. The method may be extended to a variety of loading and boundary conditions and applied to the case of ring-shaped plates.

Extensional Vibrations of Elastic Plates. R. D. Mindlin and M. A. Medick. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59—APM-4.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 561–569. 13 refs. Army-Navy-supported derivation of a system of approximate two-dimensional equations for the extensional motion of isotropic, elastic plates. The coupling between extensional, symmetric thickness-shear modes is taken into account, and the two face-shear modes are included.

The Frequency of Flexural Vibration of Rectangular Orthotropic Plates with Clamped or Supported Edges. R. F. S. Hearmon. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59—APM-8.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 537–540. 12 refs. Application of the Rayleigh method, using characteristic beam functions appropriate to the boundary conditions, to derive closed formulas for the frequencies of vibration of orthotropic plates under any combination of clamped or supported edges.

The Fundamental Frequency of a Thin, Flat, Circular Plate Simply Supported Along a Circle of Arbitrary Radius. R. Y. Bodine. (*ASME West Coast Conf., Stanford, Sept. 9–11, 1959, Paper 59—APMW-10.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 666–668.

Coupled Torsional and Longitudinal Vibrations of a Thin Bar. R. C. Di Prima. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59—A-18.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 510–512. USAF-Navy-supported study of the effect of pretwist on the natural frequencies of coupled torsional-longitudinal oscillations of thin bars. It is found that the natural frequencies of oscillations which consist primarily of torsional motion may be considerably increased, depending upon the thinness of the bar and the amount of pretwist.

Drgania Prętów na Ruchomych Podporach. Władysław Bogusz. *Rozprawy Inżynierskie*, No. 2, 1959, pp. 167–180. In Polish, with summaries in English and Russian. Analysis considering the transverse vibration of a bar rotating on three supports moving with constant velocity along the axis. The solution of the equation of vibration is obtained by finding the eigenvalues and the eigenfunctions.

Steady State Undamped Vibrations of a Class of Nonlinear Discrete Systems. P. R. Sethna, B. E. Fristedt, and V. G. Harvester. *USAF WADC TR 59-141*, Aug., 1959. 31 pp. 10 refs. Application of a perturbation scheme to the solution of steady state vibrations for a class of nonlinear discrete systems with an arbitrary number of degrees of freedom.

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The Role of Aeronautical Research in Airplane Design. A. T. Mattson. (*Rhode-Saint-Genèse, Belgium, Lectures, Feb., 1958.*) *TCEA TM 2*, Feb., 1958. 67 pp. 19 refs. Discussion of the research philosophy used in the United States in effecting and directing the development of aircraft designs. Research development in performance, propulsion systems, stability and control, flutter, and buffeting is covered.

Recent Trends in Aeronautics and Space Research in the United States. H. L. Dryden. (*CAI Spec. Anniv. Meeting, Montreal, Feb. 23, 1959.*) *Can. Aero. J.*, Nov., 1959, pp. 350–357.

Industrie Aéronautique Française. *Fusées*, Aug., 1959, pp. 90–97. In French. Presentation of design and performance characteristics of the S.E. 210 Caravelle and Bréguet 941 aircraft, the S.O.1221 Djinn helicopter, the C.450 Coleopter, and the SS 11 and SS 10 missiles.

A Canadian View of Recent Developments in Aerodynamic Research. R. J. Templin. (*CAI Spec. Anniv. Meeting, Montreal, Feb. 23, 1959.*) *Can. Aero. J.*, Nov., 1959, pp. 363–368. Discussion of research problems in VTOL aircraft capable of hovering flight, and boost-glide aircraft which may cruise at speeds approaching satellite velocity, with emphasis on possible future Canadian needs.

Air Transportation

Handling the Commercial Jet Airplane on the Ground. J. F. Horan. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint*

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48R. 13 pp. Discussion concluding that facilities for ground handling and servicing must be greatly improved to achieve optimum use of jet transports.

Bridging that Gap: What Prospects for the Vehicle Air Ferry? D. A. Whybrow. *Flight*, Dec. 11, 1959, pp. 709–711.

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A Design Study of an Aircraft Cargo-Handling System for High-Floor Aircraft. *USAF WADC TR 59-264 [AD 216085]*, June 5, 1959. 72 pp. Development of single pallet size to provide the best utilization of the compartment space of C-54, C-97, C-118, C-121, and KC-135 aircraft. Ball conveyors at aircraft door entrance provide omnidirectional movement of the pallets for proper alignment between the guide rails in the aircraft.

Handling Air Cargo. *Shorts Quart. Rev.*, Aug., 1959, pp. 13, 14. Description of a system using a standard pallet and conveyor leading from the terminal receiving bay to the aircraft freight deck.

How American Airlines Solved the Problem of Scheduling Payloads and Flight Times for Jets. F. W. Kolk. *SAE J.*, Dec., 1959, pp. 42, 43. Abridged. Application of Monte Carlo methods to flight planning, taking into account such factors as frequency distribution of wind, temperature, occupancy of altitude, routings, and fuel reserves. Provisions are made for simulating such interferences as blocked altitudes due to traffic control, circuitous routings, variable payloads, and changing conditions at point of take-off.

Relationship Between the Frequency of Technical Delays and Fleet Average Flight Duration. Roelof Brinks. *Esso Air World*, July-Aug., 1959, pp. 8, 9. Application of statistical methods to show the influence of the type of operation required by the time-table on the number of technical delays.

Airplanes

Arresting Gear

United States Air Force Development of Aircraft Arresting Gear. V. V. Vary. (*NATO AGARD 13th Flight Test Panel Meeting, Copenhagen, Oct. 21–25, 1958.*) *NATO AGARD Rep. 227*, Oct., 1958. 28 pp.

Some Tests on Befab 'Safeland' Safety Barriers. Giancarlo Salis. (*NATO AGARD 13th Flight Test Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 228*, Oct., 1958. 28 pp. Evaluation of an arresting gear for several aircraft types. The results show that braking action is smooth enough not to affect the pilot, and damage to the aircraft is easily repairable at the squadron second line maintenance service.

Control Systems, Automatic Pilots

Single-Degree-of-Freedom Simulator Investigation of Effects of Summing Display-Instrument Signals on Man-Machine Control. J. W. McKee. *U.S., NASA TN D-148*, Dec., 1959. 30 pp. Study using an analog computer of a man's ability to control "on instruments" an inertia with a proportional acceleration control.

Flight Investigations of Automatic Stabilization of an Airplane Having Static Longitudinal Instability. W. R. Russell, S. A. Sjoberg, and W. L. Alford. *U.S., NASA TN D-173*, Dec., 1959. 32 pp. Description of an experimental program conducted to determine the capabilities of three types of automatic control systems. These are: a normal-acceleration-command control system, a pitch-rate-command control system, and a pitch-damper system.

Note on the Number of Powered Flying Control Movements Measured in Flight. *Gt. Brit., AAEE Rep. Tech/169*, Oct. 1, 1959. 9 pp. Measurement of the frequency with which control movements of different ranges are made during flight of two aircraft.

An Electrodynamic Method of Exciting Servo-Tabs for Flight Flutter Testing. W. H. Johnson. *Gt. Brit., RAE TN Struc. 269*, July, 1959. 14 pp.

Power Supply Requirements for Powered Controls After Engine Failure. J. G. Walker. *Gt. Brit., RAE TN Aero. 2609*, July, 1959. 10 pp. Proposal of a standard duty cycle, prepared after examination of available flight test records, for use in the calculation of the emergency power supply requirements for powered controls after failure of the aircraft engines.

The Hydrogen-Peroxide Rocket Reaction-Control System for the X-1B Research Airplane. J. E. Love and W. H. Stillwell. *U.S., NASA TN D-185*, Dec., 1959. 28 pp.

Description

Bristol 188. *Flight*, Dec. 11, 1959, pp. 707, 708. Survey of design characteristics of supersonic research aircraft.

F-105 Spearheads TAC Fighter Forces. R. I. Stanfield. *Av. Week*, Dec. 28, 1959, pp. 37, 39, 41, 43, 45. Presentation of the design, performance, and systems characteristics of the Republic fighter-bomber.

Airco D.H. 121. *de Havilland Gazette*, Oct., 1959, pp. 152–157. Presentation of the design, performance, and systems characteristics of a short-haul airliner.

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Design Processes for High Speed Flight. B. O. Heath. (*NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 215*, Oct., 1958. 30 pp. Survey of earlier supersonic design problems and discussion of the current experience of temperature as a design parameter. New materials and methods of presenting their properties at high temperature are also included.

Safety and Safety Factors for Airframes. A. M. Freudenthal. (*NATO AGARD 6th Structures & Materials Panel Meeting, Paris, Nov. 4–8, 1957.*) *NATO AGARD Rep. 153*, Nov., 1957. 26 pp. 13 refs. Analysis covering the concept of structural safety of airframes on the basis of its relation to the probability of structural failure in order to establish procedures for the quantitative evaluation of safety factors for a predetermined acceptable risk of failure.

120,000 Man-Hours Pay Off in Boeing 707 Redesign Program. R. M. Morgan. *SAE J.*, Dec., 1959, pp. 60–62. Abridged. Discussion of design problems resulting from postdelivery experience.

Landing, Landing Loads

An Evaluation of the Factors Which Influence the Selection of Landing Approach Speeds. F. J. Drinkwater, III, G. E. Cooper, and M. D. White. (*NATO AGARD 13th Flight Test Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 230*, Oct., 1958. 13 pp.

Ground Deceleration and Stopping of Large Aircraft. Appendix—**Analysis of Some Factors Affecting Deceleration and Stopping Distance.** J. A. Zalovcik. (*NATO AGARD 13th Flight Test Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 231*, Oct., 1958. 49 pp. Discussion of various sources of deceleration, such as wheel braking, aircraft drag, aerodynamic brakes, parachutes, and reversed thrust. The effect of tire friction, wheel loading, and brake capacity on wheel braking, as well as the effect on stopping distance of aircraft handling techniques involving the use of elevators, flaps, spoilers, and nose-high attitude angles are covered in detail.

"Autoland"—A Blind Landing System for Aircraft. *Electronic Eng.*, Sept., 1959, pp. 534, 535. Description of a device developed at RAE which combines the ILS with a magnetic leader cable for azimuth guidance and a radio altimeter for height guidance.

Airplane and Engine Responses to Abrupt Throttle Steps as Determined from Flight Tests of Eight Jet-Propelled Airplanes. M. D. White and B. A. Schlaff. *U.S., NASA TN D-34*, Sept., 1959. 39 pp. Determination of aircraft and engine dynamic responses to abrupt throttle movements in conjunction with a generalized landing-approach investigation. The thrust responses of the engines and the corresponding acceleration responses of the aircraft are presented. The relationship of these responses to pilots' ratings of aircraft approach characteristics is indicated.

Landing Gear

Electra Nose Steering. *Lockheed Field Serv. Dig.*, May-June, 1959, pp. 3–5. Review of nose wheel castering and centering features as a basis for subsequent discussion of these factors as they relate to the nose wheel steering controls, rigging, and system operation.

Operating Characteristics, Economics

American's Experience with the 707. M. G. Beard. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 62T.* 9 pp.

McDonnell Model 119A Air Force Flight Evaluation. Appendix I—**Data Analysis Methods.** Appendix II—**General Aircraft Information.** Appendix III—**Test Data Corrected for Instrument Error.** Ch. O. Johnson and F. E. Cole. *USAF FTC TR 59-25*, Sept., 1959. 152 pp. Description of flight tests indicating that the aircraft performance equals, or is better than, the contractor's estimated data for take-off and climb performance. However, it does not meet the general design specifications for range, cruise speed, and landing distance.

The Performance Testing of Military Aircraft-Carrier Aircraft. R. P. Dickinson. (*NATO AGARD 13th Flight Test Panel Meeting, Copenhagen, Oct. 21–25, 1958.*) *NATO AGARD Rep. 232*, Oct., 1958. 10 pp. Brief description of the operation of carrier-borne aircraft, with a comparison to other military aircraft in terms of performance assessment. Factors affecting the determination of recommended approach speed and of wind-speed limitations for catapult take-off are discussed, and an indication is given of the extensive instrumentation needed during trials.

KC-135A Performance Test with Leading Edge Flaps. M. H. Yancey, Jr., and Ch. L. Gandy, Jr. *USAF FTC TR 58-26, Add. 2*, Oct. 5, 1959. 60 pp.

The Lockheed Electra—What It Is, and What It Does. Charles Froesch. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 62S.* 11 pp. Discussion of some early operational experiences with the Electra.

Landing and Take-Off Performance; A Definition of the Problem—Especially Required by SR-422A. M. B. Spaulding, Jr. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 60R.* 13 pp.

Jet Transport Problems During Takeoff and Landing. W. E. Rhoades and R. E. Coykendall. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 60S.* 8 pp.

Ways of Improving Takeoff and Landing. F. W. Kolk. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 607.* 12 pp. Recommendations including installation of leading edge, high lift devices which can be retrofitted to present day aircraft; the retrofit or new purchase of aircraft powered by turbofan engines that have an inherently higher take-off thrust to cruise thrust ratio; and the use of boundary layer controls actuated by turbine discharge gas.

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The Introduction of Jet Transport. C. H. Jackson. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 62R.* 6 pp. Discussion of the problems encountered in the operation of the Comet IV.

Vorbereitungen für den Einsatz eines Strahlverkehrsflugzeuges. W. Rott. *Luftfahrttechnik*, Oct. 15, 1959, pp. 340–346. In German. Survey of simulated-flight results obtained on a turbojet airliner, covering flight path, cruising altitude, duration of flight, and fuel consumption.

How Much Runway Does a Turbine Transport Need? Robert Horonjeff and Richard Coykendall. *Bus./Coml. Av.*, Oct., 1959, pp. 26–29. Discussion of the principles of the new take-off regulations setting runway lengths for safe aircraft operation.

Airports

Special Issue: Airports and Their Equipment. *Flight*, Dec. 4, 1959, pp. 672–700. *Partial Contents:* Airport Equipment—And Why, J. W. R. Taylor. Boeing 707s on Airports Round the World, John Stroud. Trends in Airport Planning, G. W. Stallibrass. International Airports—Facts and Figures. A Girdle Round the Earth, G. L. Marchault. Airport Installations and Equipment.

The Landing Capacity of a Runway. Alfred Blumstein. *Oper. Res.*, Nov.-Dec., 1959, pp. 752–763. Development of an expression for the landing capacity (or service rate) of a single runway in which aircraft are restricted by a minimum space separation at the beginning of a common glide path and by a minimum time separation at the runway. The conditions at any terminal may be inserted to determine its characteristic landing capacity.

Aviation & Space Medicine

An Account of Experiments in Which Two Monkeys Were Recovered Unharmed After Ballistic Space Flight. Ashton Graybiel, R. H. Holmes, D. E. Beischer, G. E. Champlin, G. P. Pedigo, W. C. Hixson, T. R. A. Davis, N. L. Barr, W. G. Kistler, J. I. Niven, Edward Wilbarger, D. E. Stullken, W. S. Augerson, Robert Clark, and J. H. Berrian. *Aerospace Med.*, Dec., 1959, pp. 871–931. 13 refs. Description of two experiments in which three monkeys were carried in a Jupiter missile 300 miles into space. Details are given on the construction of the biocapsules, the provisions for a closed life support environment, the equipment and arrangements for monitoring the response of the monkeys, and the experimental findings.

Sustained Operant Behavior in Mice; A Model for Behavioral Research in Biosatellites. F. H. Rohles, Jr., and M. E. Grunzke. *USAF WADC TN 59-299*, Aug., 1959. 12 pp. Study that measures the simple yet stable response patterns in a mouse under conditions of space flight.

Über den Einfluss von langfristiger kontinuierlicher Hypoxie auf die Serum-Glutaminsäure-Oxalessigsäure-Transaminase. K. Weiner. *DVL Bericht No. 101*, Sept., 1959. 27 pp. 43 refs. Westdeutscher Verlag, Köln & Opladen. In German. Discussion, based on animal tests, to determine the effect of lasting continuous hypoxy upon the glutamine acid–oxalatic acetic acid-transaminase in the serum.

General Motors

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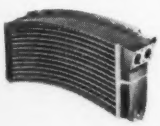

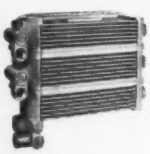

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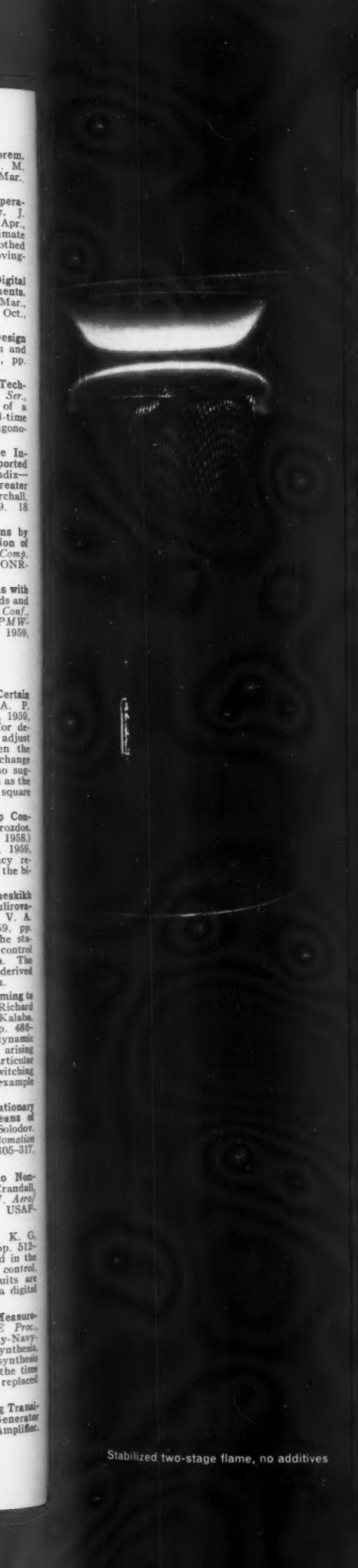

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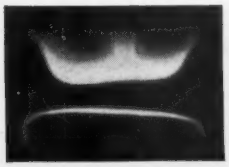
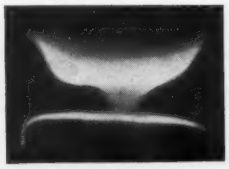


Iron carbonyl, an antiknock



Ethyl nitrate, a proknock

Iron carbonyl retards, ethyl nitrate accelerates central portion of cool flames.

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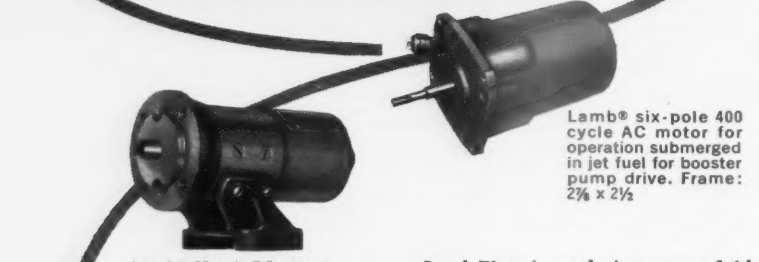

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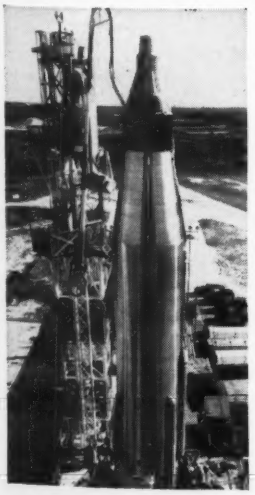

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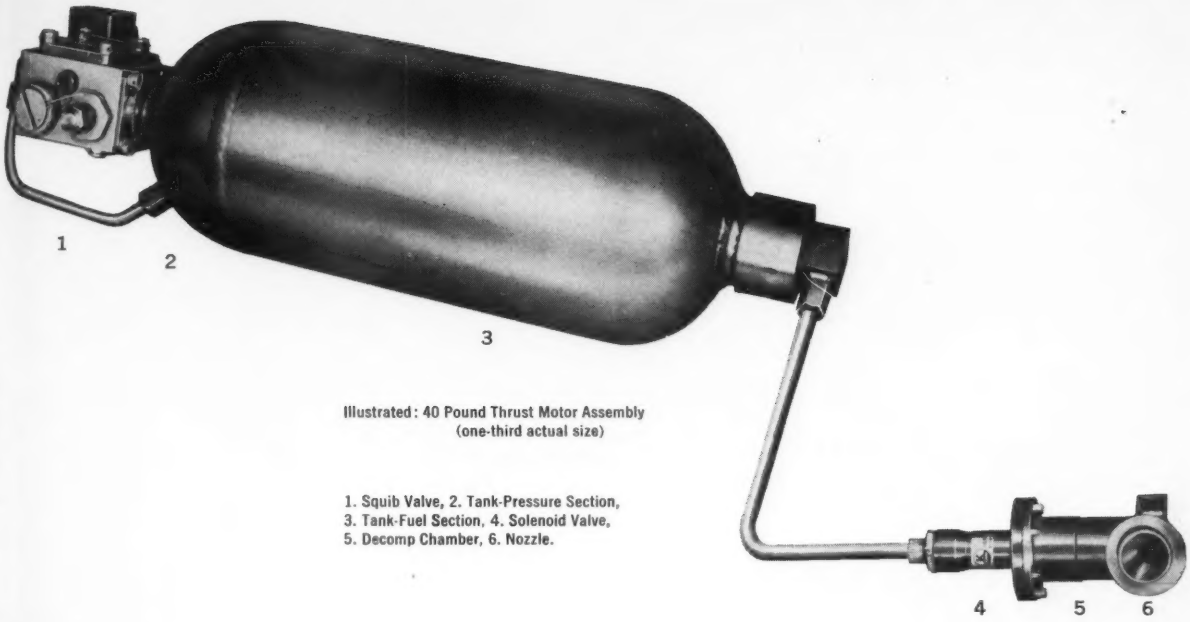

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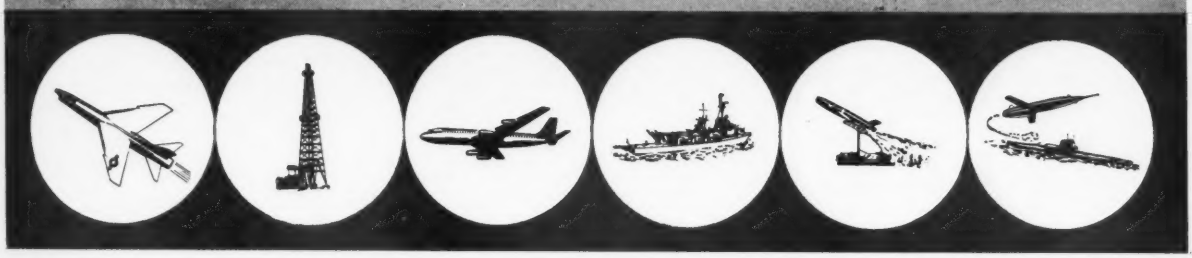

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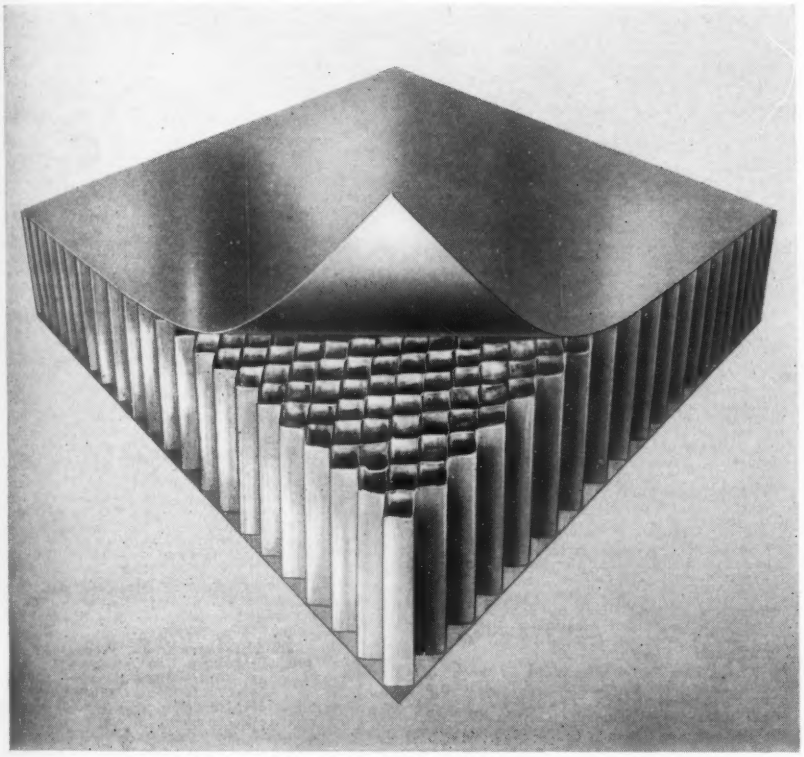

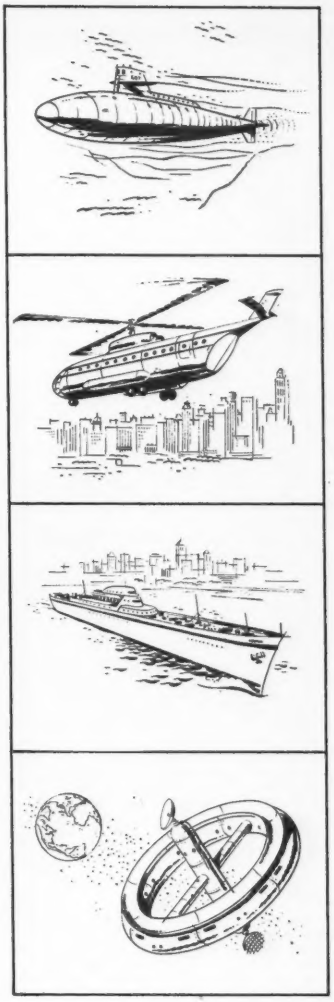

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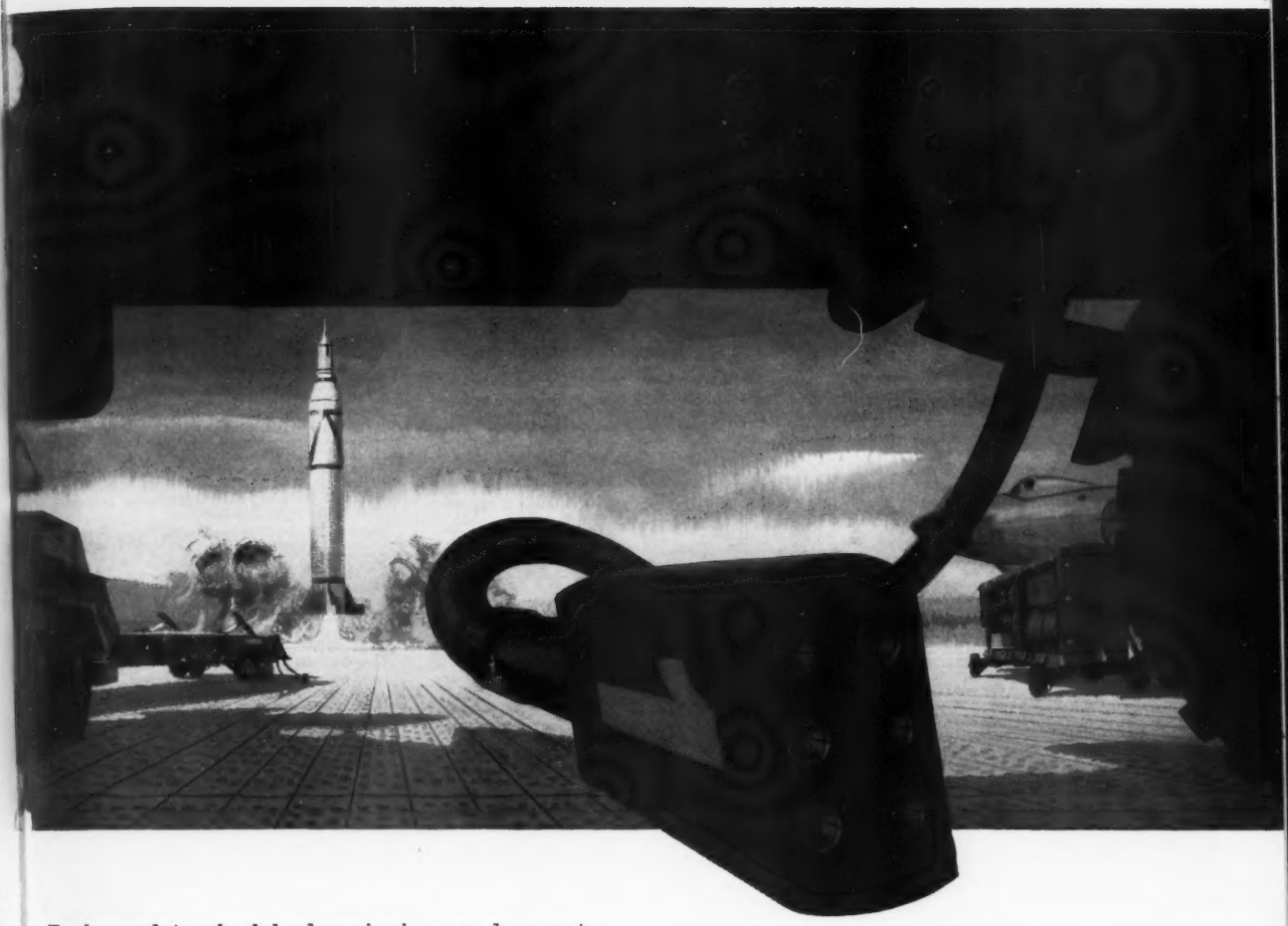
GROUND SUPPORT BEARINGS



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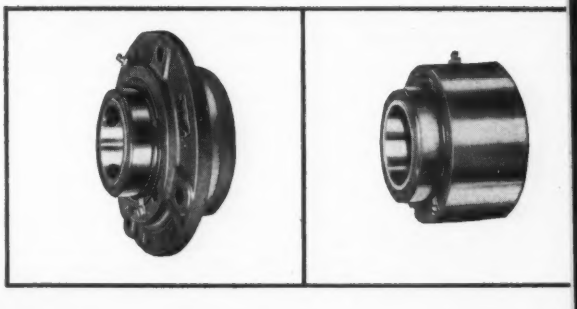

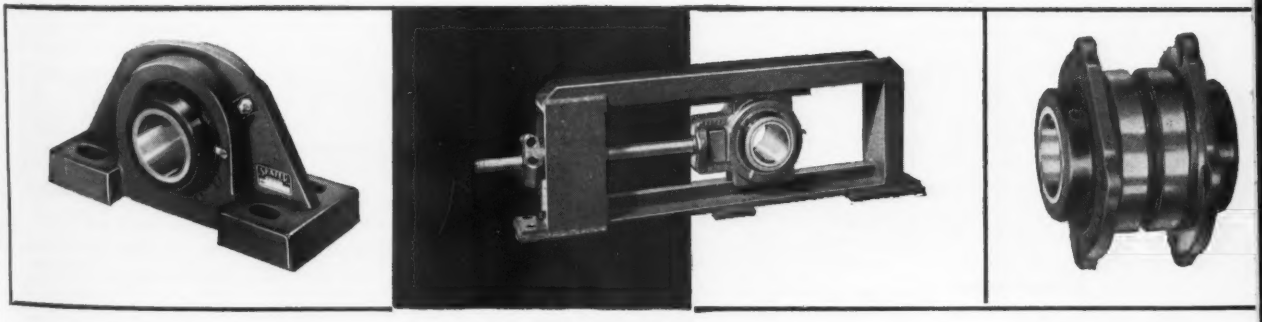

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Titanium Provides Notch-Ductile Rocket Cases. A. N. Eshman. *Space/Aeronautics*, Dec., 1959, pp. 73, 74, 76, 78. Comparison of three alloys with high-strength steels for use in rocket cases, and description of five methods of fabrication.

Research on Strain Aging Effects in Titanium. H. S. Gurev and W. M. Baldwin, Jr. *USAF WADC TR 59-223*, Sept., 1959. 60 pp. 54 refs. Investigation of the effects of varying interstitial element content (oxygen, carbon, and nitrogen) on the tensile properties of alpha-beta titanium alloy, Ti-140A, at test temperatures ranging from room temperature to above 1,000°F.

Nonmetallic Materials

The Effects of Simulated Space Environments on Cushioning Materials. D. N. Keast and J. J. Baruch. *USAF WADC TR 58-667*, Sept., 1959. 98 pp. Measurement of some properties of several types of cushioning materials at different temperatures and pressures. Static and dynamic stress-strain curves and vibration transmissibility characteristics are obtained for glass fiber, latex bound hair, polyurethane foam, silicone rubber foam, and crushable paper honeycomb materials.

Damping Adhesives Solve Missile Vibration Problems. B. J. Lazan and J. E. Ruzicka. *SAE J.*, Dec., 1959, pp. 69–71. Abridged.

How Storage Conditions of Glass Fabric Affects Strength of Reinforced Laminates. B. G. Heebink and Gordon Stevens. *SPE J.*, Jan., 1960, pp. 39–43, 45.

The Dynamic Mechanical Properties of Epoxy Resins. D. H. Kaelble. *SPE J.*, Dec., 1959, pp. 1071–1077. Description to tests made to determine the dynamic properties of thermoset epoxy resins in the glassy state and through the glassy transition region. The experimental procedure and equipment are described, and the results are compared.

Epoxy Resins for the Encapsulation of Electronic Components. A. E. Ringwood. *SPE J.*, Jan., 1960, pp. 93–100. Presentation of design information on materials for encapsulation and impregnation of electronic equipment which must operate over the range of −65° to 90°C.

Properties of Silicone Rubber for High Temperature Static Seals. H. E. Todd and J. F. Miazga. *SAE Natl. Aero. Meeting, New York, Mar. 31–Apr. 3, 1959, Preprint 50V.* 32 pp.

Testing Methods

Apparatus for the Measurement of Internal Friction and Dynamic Young's Modulus at Kilocycle Frequencies. E. W. Dickson and H. Strauch. *J. Sci. Instr.*, Oct., 1959, pp. 425–428. 12 refs.

Statistical Evaluation of Data from Fatigue and Creep-Rupture Tests. I—Fundamental Concepts and General Methods. Waloddi Weibull. *USAF WADC TR 59-400, Pt. I*, Sept., 1959. 73 pp. 19 refs. Classification of fatigue tests into three types considering the appropriate method of evaluating the data. Fundamental statistical concepts, general methods, and useful tools are presented. The possibilities of estimating distribution parameters are examined.

Technique Non Destructive pour la Détection de la Sensibilité à la Corrosion sous Tension des Alliages Aluminium-Magnésium. M. P. A. Jacquet. *La Recherche Aéronautique*, Sept.–Oct., 1959, pp. 25–33. In French. Application of the nondestructive method to electrochemical testing of aluminum-magnesium alloys in order to determine their susceptibility to intergranular corrosion under tension.

An Experimental Study of the V-Notch Fatigue Test. D. S. Dugdale. *J. Mech. & Phys. Solids*, Oct., 1959, pp. 282–287. Description of rotating bending tests on sharply notched specimens of several materials. Logarithmic plotting shows S-N curves consisting of straight lines of a gradient common to all materials, suggesting a power law of crack propagation. When residual stress was introduced by preloading the specimens, results following a similar pattern were obtained.

La Résistance Thermique des Joints. J. J. Bernard. *(NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.) NATO AGARD Rep. 212*, Oct., 1958. 20 pp. In French. Description of apparatus constructed at ONERA for studying the thermal contact resistance between conductors or between conductors and insulators, as well as the extent to which this varies as a result of the tightening pressure.

Prediction of Impact Resistance from Tensile Data. R. M. Evans, H. R. Nara, and E. G. Bobalek. *SPE J.*, Jan., 1960, pp. 76–83. 25 refs. Discussion of tensile tests determined at strain rates which correlate with impact resistance tests.

Mathematics

Differential Equations

Integration Methods for Differential Equations. S. Schlesinger. *J. Astron. Sci.*, Winter, 1959, pp. 53–57. Study of various methods for the numerical integration of differential equations with emphasis on second-order differential equations in which the first derivatives are absent.

Non-Uniqueness in Cauchy's Problem for Differential Equations of Elliptic Type. A. Plis. *U. Chicago Dept. Math. TN 5 (AFOSR TN 59-1034)*, Aug., 1959. 9 pp.

Functions & Operators

New Formulas for Computing Incomplete Elliptic Integrals of the First and Second Kind. A. R. DiDonato and A. V. Hershey. *Assoc. Comp. Mach. J.*, Oct., 1959, pp. 515–526. Development of a method for computing two basic functions which have frequent application in applied mathematics. The calculation of elliptic integrals by the series expansions is compared with the calculation by the previously established Landen transformation used by Legendre. The computing program in the NORC subrutine is described.

On Quadratic Programming. E. M. L. Beale. *Nav. Res. Logistics Quart.*, Sept., 1959, pp. 227–243. OOR-sponsored description of a previously given algorithm for minimizing a convex quadratic function of variables subject to linear inequalities. Some extensions of the algorithm are indicated.

Tables for Bivariate Osculatory Interpolation Over a Cartesian Grid. H. E. Salzer and G. M. Kimbro. *Convair-Astronautics Paper*, 1958. 40 pp.

Groups

Which Lie Groups Are Homotopy-Abelian? Ioan James and Emery Thomas. *U. Calif. Dept. Math. TR 11 (AFOSR TN 59-982)*, Sept., 1959. 7 pp. 12 refs.

Matrices

Determinants and Matrices. A. D. Kraus and G. F. Ross. *Elec. Mfg.*, Dec., 1959, pp. 133–148. Presentation of data providing basic tools for the broad concept of network and circuit study and analysis, as well as for engineering problems which can be derived from the electric circuit analogy.

La Recherche des Valeurs Propres Dominantes et Subdominantes d'une Matrice Réelle ou Complexe. D. Clerc. *La Recherche Aéronautique*, Sept.-Oct., 1959, pp. 53–58. In French. Analysis showing that the method used in the case of matrices with real eigenvalues can be extended to cover the case of any given real or complex matrices. The applicability of the method to vibration problems is indicated.

Numerical Analysis

Derivation and Tabulation of Molecular Integrals. Appendix A—**Method of Computation of Nuclear-Attraction Integrals.** Appendix B—**Method of Computation of Overlap Integrals.** Appendix C—**Elliptical-Coordinate Method of Computation of Overlap Integrals.** R. C. Sahni and J. W. Cooley. *U.S., NASA TN D-146*, Dec., 1959. 39 pp. Presentation of integrals required for the computation of wave functions of atoms and diatomic molecules. Tabulated material for overlap, nuclear-attraction, kinetic-energy, potential-energy, Coulomb, hybrid, and exchange integrals is presented.

Routh Test Function Methods for the Numerical Solution of Polynomial Equations. C. Mack. *Quart. J. Mech. & Appl. Math.*, Aug., 1959, pp. 365–378. 15 refs. Development of two iterative methods for the numerical solution of polynomial equations with real coefficients.

Dual Fourier-Bessel Series. J. C. Cooke and C. J. Tranter. *Quart. J. Mech. & Appl. Math.*, Aug., 1959, pp. 379–386. Presentation of a method for determining the coefficients a_n in the "dual" Fourier-Bessel series.

The Secant Method for Simultaneous Nonlinear Equations. Philip Wolfe. *Assoc. Comp. Mach. Commun.*, Dec., 1959, pp. 12, 13.

Physical Applications

Solution of Modified Linear Simultaneous Equations. W. J. Goodey. *Aircraft Eng.*, Dec., 1959, pp. 358, 359, 364. Solutions for a set of linear simultaneous equations, that have already been solved for one particular set of values of the coefficients, and must be solved again when some of the coefficients are altered. In the structural context the problem is to find the effect of altering the sizes of some of the members of a structure.

On the Method of Elastic Solutions. I. I. Vorovich and Yu. P. Krasovskii. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 701–704. Translation. Application of the method of elastic solutions for the basic problems in the theory of small elasto-plastic deformations without any assumption on the smallness of the parameter entering into the problem. At the same time the existence of a generalized solution is established.

Integration of the Boundary-Layer Equations. V. Ya. Shkadov. *Sov. Phys. - Dokl.*, Dec., 1959, pp. 585–588. Translation. Presentation of a method for reducing the boundary-layer problem, which is described in terms of nonlinear partial differential equations, to the solution of ordinary linear differential equations with boundary conditions.

Extention of a Variational Theorem for Creep to Curvilinear Coordinates. Madeline Goulard. *Purdue U. Sch. Aero. Eng. Rep. S-58-1*, Aug., 1958. 7 pp. Development of a variational theorem for creep similar to that established by Sanders, McComb, and Schlechte, but applicable to curved plates and shells. A similar theorem is formulated, using curvilinear coordinates and a more rigorous tension notation.

On Some Fredholm Integral Equations Arising in Diffraction Theory. C. H. Yang. *NYU Inst. Math. Sci. Div. Electromagn. Res., Res. Rep. BR-31 (AFOSR TN 59-944)*, Aug., 1959. 18 pp.

Multifunctional Circuits in Functional Canonical Form. H. A. Curtis. *Assoc. Comp. Mach. J.*, Oct., 1959, pp. 538–547. Extension of previously obtained results including the application of the fundamental functional canonical form to multiple output circuits and the formulation of cost bounds on these circuits, as well as the use of multifunctional canonical form in the design of single output circuits.

The Bang Bang Servo Problem Treated by Variational Techniques. C. A. Desoer. *Info. & Control*, Dec., 1959, pp. 333–348. 13 refs. *USAF*-supported analysis considering the following problem: given a set of arbitrary initial conditions, determine the forcing function that leads to the equilibrium (origin of the phase space) in the shortest time. The problem is treated by variational techniques and establishes properties of the optimum forcing function.

Bounds for the Eigenvalues of Some Vibrating Systems. Dallas Banks. *Carnegie Inst. Tech. Dept. Math. TR 28 (AFOSR TN 59-508) [AD 216273]*, June, 1959. 53 pp. 14 refs. Analysis considering the nature of density functions for which the greatest lower bounds of the eigenvalues are attained when other restrictions are placed on them.

General Differential Formulae of the Complete Projective Relations Between Planes. B. Hallert and L. Ottoson. *KTH Trans. 140*, 1959. 15 pp. Derivation of formulas for arbitrary mutual positions of the two planes and for different arrangements of the axes of rotations and sequences of rotations. Applications are made to aerial and terrestrial photogrammetry.

Numerical Integration of the Primitive Equations on the Hemisphere. N. A. Phillips. *Mo. Weather Rev.*, Sept., 1959, pp. 333–345. 17 refs.

Probability, Statistics

A Note on Approximations to Discrete Probability Distributions. D. T. Brown. *Info. & Control*, Dec., 1959, pp. 386–392. Presentation of an iterative method which gives an optimum approximation to the joint probability distribution of a set of binary variables given the joint probability distributions of any subsets of the variables (any set of component distributions).

A Functional Equation Technique for Obtaining Wiener Process Probabilities Associated with Theorems of Kolmogorov-Smirnov Type. J. Kiefer. *Cambridge Philos. Soc. Proc.*, Oct., 1959, pp. 328–340. Navy-sponsored research.

The Central Limit Theorem for a Convergent Non-Homogeneous Finite Markov Chain. J. L. Mott. *Royal Soc. (Edinburgh) Proc., Sect. A*, 1958–1959, Pt. II, pp. 109–120.

Variational Principle for Compatibility Equations. H. Zorski. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 445, 446.

Topology

The Shortest Path Through Many Points. Jullian Beardwood, J. H. Halton, and J. M. Hammersley. *Cambridge Philos. Soc. Proc.*, Oct., 1959, pp. 299–327. 25 refs. Presentation of the proof that the length of the shortest closed path through n points in a bounded plane region of area v is "almost always" asymptotically proportional to $\sqrt{(nv)}$ for large n, and extension of this result to bounded Lebesgue sets in k-dimensional Euclidean space.

The Influence of Edges and Corners on Potential Functions of Surface Layers. Rolf Leis. *NYU Inst. Math. Sci. Div. Electromagn. Res., Res. Rep. BR-29 (AFOSR TN 59-934)*, June, 1959. 21 pp. Discussion of the potential functions of multiple surface layers which behave singularly when approaching the boundary of the surface. The degree of the singularities of these functions and their derivatives are studied.

Transforms

Lectures on Applied Mathematics—The Laplace Transformation. F. D. Murnaghan. *U.S., Navy Dept., David Taylor Model Basin, Rep. 1346*, June, 1959. 166 pp. Presentation of 19 papers on the Laplace transformation and its application to linear ordinary differential equations with variable coefficients, to linear partial differential equations with two independent variables and constant coefficients, and to the determination of asymptotic series.

(Continued on page 103)

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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ACOUSTICS, SOUND, NOISE

THEORETICAL INVESTIGATION OF THE SOUND FIELD PRODUCED DOWNSTREAM OF A CHOKED TWO-DIMENSIONAL CHANNEL DUE TO UNSTEADY UPSTREAM ENTROPY FLUCTUATIONS. J. P. Appleton and H. J. Davies. Gt. Brit., ARC CP 461, 1959. 10 pp. BIS, New York, $0.36. Study considering the two-dimensional flow of an ideal compressible fluid bounded by two rigid, nonconducting, parallel walls of infinite extent. A shock wave normal to the rigid boundaries divides the flow into subsonic and supersonic regimes. In the supersonic region, a normal static temperature variation, which is sectionally invariant but fluctuates periodically with time, when convected through the shock wave results in a perturbation of the flow in the subsonic region. By assuming that the magnitude of the fluctuations of the static temperature is small, an expression for the acoustic pressure fluctuation in the downstream part of the gas is deduced.

ON THE AERODYNAMIC NOISE OF A RIGID FLAT PLATE MOVING AT ZERO INCIDENCE. Alan Powell. ASA J., Dec., 1959, pp. 1649-1653. Discussion of the aerodynamic noise resulting from the subsonic flow over a flat plate. "Surface" noise due to fluctuating pressure is postulated to vanish by the image argument, except near the edges of the plate, where it is more appropriately called edge noise. The contribution from fluctuating shear stresses is likely to be much smaller and has been, therefore, neglected. Quadrupole radiation takes place from the turbulence of the boundary layer, producing layer noise, and also from the turbulent wake, producing wake noise. Together, the latter two are suggested to have a spectrum with a single peak, bounded by slopes like f^2 and $f^{-7/4}$. Their noise power depends on nearly the eighth power of the velocity - i.e., becomes of increasing importance with speed. Analytical details rest on similarity concepts; the spectra in particular are subject to certain conditions.

SUPERSONIC BOOM OF WING-BODY CONFIGURATIONS. I. L. Ryhming and Y. A. Yoler. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-20. Members, $0.50; nonmembers, $1.00. 23 pp. 10 refs. Analysis considering the supersonic boom occurring in steady, level flight due to the effects of body volume, wing volume, wing incidence or lift, and wing-body interference. The contribution in the far field of each of these factors can, in any given azimuthal plane, be represented as that of an equivalent body of revolution. This concept is developed to investigate the possibilities of using interference among the components of a wing-body configuration to reduce or suppress the boom due to lift. Results of wind-tunnel experiments are also presented and discussed in the light of theoretical considerations.

AERODYNAMICS, FLUID MECHANICS

Aerothermochemistry, Dissociation, Ablation

INVISCID FLOW WITH NON-EQUILIBRIUM MOLECULAR DISSOCIATION FOR PRESSURE DISTRIBUTIONS ENCOUNTERED IN HYPERSONIC FLIGHT. M. H. Bloom and M. H. Steiger. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-26. Members, $0.50; nonmembers, $1.00. 27 pp. 36 refs. Study of one-dimensional inviscid nonequilibrium flows of a two-component model gas with prescribed pressure variation and an average reaction-rate based on recent data for oxygen recombination. These flows are interpreted in relation to the flow along streamlines around blunt hypersonic bodies. Assuming equilibrium conditions in the subsonic region, it is estimated that the flow in the initial supersonic expansion region, which is approximately of Prandtl-Meyer character, will be chemically frozen with respect to the molecular dissociation of the primary components under the hypersonic, high-altitude flight conditions considered. The flight conditions consist of flight velocities between 15,000 and 25,000 ft. per sec. at altitudes between 154,000 and 246,000 ft. Furthermore, on bodies of small surface inclination beyond the nose, the flow will continue to be effectively frozen for at least 20 ft. downstream of the nose. The problem of distinguishing a dimensionless length-reaction-rate pa-

rameter, which characterizes the extent of departure from equilibrium or from frozen behavior in the flow fields, is discussed.

HEAT PROTECTION BY ABLATION. R. M. Wood and R. J. Tagliani. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-8. Members, $0.50; nonmembers, $1.00. 15 pp. Study covering the desirable thermal and ablation properties of materials used for protecting load-carrying structures from excessive temperatures, and their interrelationship with the environment to which such protective coatings are subjected. The assumption of an equivalent square wave heat-time input for any actual environment is discussed and justified for radically different environmental situations, including ICBM, Mars entry, anti-ICBM, manned entry, and nozzle applications. Using the square wave heat input assumption, the unit coating required is presented as a function of intensity and duration of heating for several different protective coatings. Three domains of heating are categorized: (1) almost complete ablation, wherein the most important material property is heat absorbed per pound of material lost; (2) partial ablation, wherein density and conductivity are as important as ablation properties; and (3) no ablation, wherein ordinary thermal properties are all important. The results are summarized by the graphical representation of the relative coating weights required by some popular protection materials for a number of different environmental situations.

SCHMELZKÜHLUNG SCHNELLFLIEGENDER BALLISTISCHER KÖRPER BEIM WIEDEREINTRITT IN DIE ERDATMOSPHÄRE. Ernst Adams. (DGRR Jahresfachtagung, Munich, May, 1959.) Raketentech. & Raumfahrtforsch., Oct.-Dec., 1959, pp. 97-104. In German. Study covering the ablation cooling of ballistic missiles re-entering the earth's atmosphere. The thermal properties of the molten film in the vicinity of the forward stagnation point of the missile are considered. Calculations are made and curves are presented to illustrate the heat process as a function of time. The steady-state properties of ablating material are then considered with respect to dynamic and thermal parameters and in relation to flight speed and altitude.

Aerothermodynamics

BOUNDARY-LAYER DISPLACEMENT AND LEADING-EDGE BLUNTNESS EFFECTS IN HIGH TEMPERATURE HYPERSONIC FLOW. H. K. Cheng, J. G. Hall, T. C. Golian, and A. Hertzberg. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-38. Members, $0.50; nonmembers, $1.00. 81 pp. 66 refs. USAF-Navy-sponsored theoretical and experimental investigation of the interaction of the two effects. The basic shock-layer concept is extended and a detached shock layer is introduced to account for bluntness. In the boundary layer, the approximate solution is found to be governed by local similarity. For the specific heat ratio γ close to unity, the leading approximation for flat-plate afterbodies yields a solution agreeing with blast-wave theory at one limit and strong-interaction theory at the other. Similarly, flow over a blunted edge is treated. A hypersonic similitude involving strong shocks is also given. Measurements were made on a flat plate for surface heat-transfer distributions and schlieren studies were done for zero and nonzero incidence. The range of test conditions encompassed the limiting cases of dominant bluntness and dominant viscous interaction effects. Comparison with theory shows a good correlation in terms of the similitude variables characterizing combined effects of boundary-layer displacement and bluntness.

HEAT TRANSFER, RECOVERY FACTOR AND PRESSURE DISTRIBUTIONS AROUND A CIRCULAR CYLINDER NORMAL TO A SUPERSONIC RAREFIED-AIR STREAM. O. K. Tewfik and W. H. Giedt. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-46. Members, $0.50; nonmembers, $1.00. 15 pp. 13 refs. ONR-supported presentation of test results for a Mach number range of 1.3 to 5.7, a Reynolds number range of 37 to 4,100, and cylinder wall average temperature levels of 90°K. and 210°K. Study of the results yielded (1) a correlation equation for the stagnation-point Nusselt number as a function of the Reynolds number just after the normal part of the detached bow shock wave; and (2) Fourier series expressions for the heat-transfer coefficient and pressure coefficient distributions in terms of the stagnation point values. Comparison with theoretical studies shows that exceptionally good agreement for the heat-transfer coefficient distribution was obtained with Lee's theory. In the Mach number range of 3.55 to 5.73, the pressure decreased less rapidly with distance from the stagnation point than predicted by the modified Newtonian theory.

EVALUATION OF THERMAL PROBLEMS AT RELATIVELY LOW ORBITAL ALTITUDES. L. D. Wing. Aero/Space Engrg., Mar., 1960, pp. 58-60, 64. Presentation of a simple method for estimating the maximum and minimum heat inputs experienced anywhere on the outer skin face of an orbiting vehicle. Consideration is given to the earth-radiated energy, reflected solar energy, direct solar radiation, and heat transfer from the inner cabin wall to the outer skin. A thermal control system in which insulation is used to contain heat, thus eliminating the need for a heater, is outlined. An air ducting system is used for cooling.

Boundary Layer

EKSPERIMENTAL'NOE ISSLEDOVANIE DOZVUKOVOGO TURBULENTNOGO POGRANICHNOGO SLOIA NA PLASTINE SO VDUVOM. V. P. Mugalev. MVO SSSR VUZ Izv. Av. Tekh., No. 3, 1959, pp. 72-79. In Russian. Experimental investigation of the subsonic turbulent boundary layer over a porous plate with gas injection. The installation, comprising a porous model placed in the open working section of a wind tunnel, permitted to attain an exhaust velocity of 75 m./sec. and

temperatures up to 600°C. A Pitot tube was used to measure the variation of the velocity fields in the boundary layer, and the experimental velocity profiles were compared with those obtained by Nikuradze in the turbulent boundary layer with longitudinal pressure gradient for flows in convergent (negative angles) and divergent (positive angles) channels. It is found that the boundary layer flow is analogous to the flow over an impermeable surface in the case of a positive pressure gradient; the parameter f_w defines the effect of injection on the boundary layer.

THE EFFECT OF TIP BLUNTNESS ON BOUNDARY-LAYER TRANSITION ON A 15° INCLUDED ANGLE CONE AT M = 3.12 AND 3.81. R. H. Rogers. Gt. Brit., RAE TN Aero.2645, Aug., 1959. 39 pp. Description of tests on cones having tip radii up to 0.49 in. at zero incidence. The position of transition to turbulence in the boundary layer is found to move downstream as the tip radius increases, as long as transition is more than about 100 tip radii downstream from the tip. If transition occurs upstream of this station, its position tends to move further upstream as the tip radius increases. Pitot traverses of the boundary layer are made, showing that the Reynolds number based on momentum thickness at transition remains nearly constant in all cases (at 680 when M = 3.12 and at 600 when M = 3.81). A tentative explanation is given for the upstream movement of the transition when it occurs near the tip.

FURTHER INVESTIGATION ON THE TRANSITION OF TWO-DIMENSIONAL SEPARATED LAYER AT SUBSONIC SPEEDS. Hiroshi Sato. Phys. Soc. Japan J., Dec., 1959, pp. 1797-1810. Experimental investigation in which the laminar separated layer is excited by an external sinusoidal sound source. The wave speed and amplification rate of excited velocity fluctuation are measured. The response characteristics are found to be in good agreement with theoretical calculations based on the Orr-Sommerfeld equation. The effect of excitation becomes maximum when the frequency of external excitation coincides with that of naturally excited sinusoidal velocity fluctuation in the laminar layer. No abrupt turbulent bursts are found in the transition region. The wave form of velocity fluctuation changes gradually from sinusoidal to irregular patterns.

SOME TRANSITION PATTERNS IN AXISYMMETRIC BOUNDARY LAYERS. F. R. Hama. Phys. Fluids, Nov.-Dec., 1959, pp. 664-667. USAF-supported study of the vortex pattern, caused by a ring-shaped trip, made in a water tank for circular cylinders and a 30° cone. Over the cylinders the boundary-layer thickness is approximately equal to the radius of the cylinders. Ring-shaped vortices are shed and deformed into vortex loops in the same manner as on a flat plate. On the cone the ring-shaped vortices are stretched and then inevitably deformed into vortex loops, indicating that a mere stretching is not a sufficient mechanism for the creation of a turbulence spot. A mechanism is tentatively proposed for the final breakdown from the vortex loop.

THE TURBULENT BOUNDARY LAYER ON A FLAT PLATE IN A UNIFORM STREAM OF A COMPRESSIBLE FLUID. S. I. Kosterin and Yu. A. Koshmarov. Sov. Phys. - Tech. Phys., Jan., 1960, pp. 819-828. Translation. Analysis considering the effect of density pulsation on the distribution of velocities, temperatures, and densities in the boundary layer and, consequently, on friction and heat exchange for a plate in a gas stream. Turbulent mixing is represented according to the diagram proposed by Prandtl. A method of calculation is developed, giving results in satisfactory agreement with experiment. Comparison of the results calculated by two methods (with and without accounting for density pulsation) shows that when Mach numbers are large (M > 6), the difference in friction coefficients is from 15% to 40% of the values calculated by the method in which the density pulsation is not taken into account.

THE VELOCITY DISTRIBUTION IN A TURBULENT BOUNDARY LAYER ON A FLAT PLATE. Appendix - THE EFFECTS OF THE TURBULENT FLUCTUATING VELOCITIES ON THE MEASUREMENT OF THE MEAN VELOCITY IN THE BOUNDARY LAYER. R. A. Dutton. Gt. Brit., ARC CP 453, 1959. 24 pp. 13 refs. BIS, New York, $0.72. Discussion of results obtained experimentally by means of detailed boundary-layer traverses made on a smooth flat plate with zero pressure gradient. The velocity distributions are compared with established inner laws and velocity defect laws. The influence of the turbulent velocity fluctuations on measurements with a Pitot tube, and the effect of variation of static pressure through the boundary layer are also considered. These are shown to be appreciable in the region where the inner law is assumed to hold. Corrections also are made to some of the measurements and the resulting inner law is found to agree closely with that proposed by Coles.

NONSTATIONARY TURBULENT BOUNDARY LAYER ON A WING PROFILE AND ON A FIGURE OF ROTATION. K. K. Fedyaevskii and A. S. Ginevskii. Sov. Phys. - Tech. Phys., Jan., 1960, pp. 829-836. Translation. Development of an approximate single parameter method for calculating the parameters of the turbulent boundary layer and the position of the breakaway point when the forward motion of the body is accelerated. The method is based on a semiempirical theory of turbulence and is a generalization of a method of calculation worked out earlier for a stationary turbulent boundary layer. The only difference is that the dimensionless parameter Q depends not only on the velocity prevailing outside the boundary layer and its longitudinal gradient, as is the case for the stationary layer, but also on the derivatives of these velocities with respect to time. As an example, the turbulent boundary layer on a cylinder moving with constant acceleration or constant deceleration is considered. It is found that the nonstationary state of the boundary layer on an un-

streamlined body affects its resistance mainly because the positions of the breakaway points change at every given moment.

TURBULENT BOUNDARY LAYER MEASUREMENTS AT MACH NUMBERS FROM 8 TO 10. F. K. Hill. Phys. Fluids, Nov.-Dec., 1959, pp. 668-680. 22 refs. Navy-supported presentation of data on skin friction and heat transfer for comparison with theory. Significant results of the investigation include the relatively rapid growth of the laminar sublayer at high Mach numbers, the increase in the momentum thickness with heat transfer, the decrease in the heat transfer coefficient, and the skin friction dependence on heat transfer and pressure gradient at high Mach numbers. The velocity profiles in the turbulent portion of the boundary layer are found to extend the trend evidenced at lower Mach numbers of a fit to a power profile, but with a somewhat lower velocity index (n = 5 as compared to 7 and 9 at lower supersonic Mach numbers.) On the other hand, an exponential fit to the experimental points provides equally good agreement and satisfies better the physical conditions at the edge of the boundary layer.

Flow of Fluids

SOME CONSIDERATIONS OF THE LAMINAR STABILITY OF INCOMPRESSIBLE, PARALLEL TIME-DEPENDENT FLOWS. S. F. Shen. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-33. Members, $0.50; nonmembers, $1.00. 18 pp. Navy-sponsored presentation of the concept of "momentary stability" for dealing with time-dependent basic flows, which occurs when the kinetic energy of the disturbances, as a fraction of the kinetic energy of the basic flow, tends to decrease at any instant. The disturbance is measured on the basis of the ratio of the kinetic energy of the perturbations to that of mean flow, both averaged throughout the boundary-layer thickness and over a wave length. An analysis in made of incompressible parallel but nonsteady basic flow, upon which are superposed two-dimensional infinitesimal perturbations of the transverse wave type. The calculation procedure for the "momentary stability" of slowly changing, but otherwise completely arbitrary, basic flows is outlined. Essentially, the eigenvalue problem is taken as identical to the quasi-steady approach, but a time-dependent part of the "mode" is determined.

UNSTEADY RECTILINEAR GAS FLOW. D. Naylor. J. Math. & Mech., Jan., 1960, pp. 1-18. Study of the effect on the equations of unsteady nonisentropic rectilinear gas flow of the use of a modified stream function analogous to Crocco's stream function. This function is defined in terms of the gas speed u and the acoustic speed a, and remains constant for each fluid element during the motion. The method consists of applying certain transformations to a Lagrangian equation $x(\psi, t)$, the position at time t of the fluid element ψ. The general problem is reduced to that of a quasi-linear partial differential equation homogeneous in the second-order derivatives. For suitably prescribed distributions of entropy this equation possesses special integrals, one of which is equivalent to Martin's exact solution. Other integrals are obtained by concentrating on degenerate solutions analogous to simple waves.

SOME ASPECTS OF NON-EQUILIBRIUM FLOWS. Raymond Sedney. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-4. Members, $0.50; nonmembers, $1.00. 15 pp. 13 refs. Study of some of the general features of non-equilibrium flow, in particular, the vibrational relaxation. Those aspects of two-dimensional and axisymmetric flow behind shock waves are examined which yield significant information without requiring numerical solution of the governing equations. After a discussion of the appropriate thermodynamics of a vibrational relaxing diatomic gas, the governing equations are transformed to yield the generalization of Crocco's theorem which relates the entropy change to the vorticity. Next, a derivation and a discussion of the characteristic equations are given. Using the appropriate shock transition relations and the equations of motion, the streamwise gradients of the flow variables are obtained employing natural coordinates. An exact solution for flow over a cusped body is obtained. Flow over a wedge near the tip and far from the tip is considered. It is found that far from the tip a boundary-layer-type phenomenon occurs.

A SIMPLE NUMERICAL SOLUTION OF THE FLOW AROUND A BLUNT BODY IN A SUPERSONIC STREAM WITH APPLICATION TO REAL GASES. G. A. Bird. Australia, WRE TN HSA 52, Sept., 1959. 24 pp. 11 refs. Study showing that a satisfactory numerical solution of the steady inviscid flow behind an axisymmetric or plane detached shock wave can be obtained by a method which uses only elementary forms of the equations of motion. Thus, the calculations may be based on real gas properties, neglecting the perfect gas assumption when it ceases to be applicable in hypersonic flow. Results are given for the flow behind a paraboloidal shock wave in the flow of air at a Mach number of 20 for the three assumptions of perfect gas, real gas in thermodynamic equilibrium everywhere, and real gas with the composition frozen during expansion processes. Also presented are results for the flow behind the shock wave actually produced by a flat-nosed body of revolution at a Mach number of 2.4.

FLUCTUATING LIFT AND DRAG ACTING ON A CYLINDER IN A FLOW AT SUPERCRITICAL REYNOLDS NUMBERS. Appendix - AN EXAMPLE FOR THE CALCULATION OF ELASTIC RESPONSE. Y. C. Fung. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-6. Members, $0.50; nonmembers, $1.00. 19 pp. 27 refs. Presentation of measurements for Reynolds numbers up to about 1.4×10^6 on both a stationary cylinder and a cylinder subjected to forced oscillations of specific amplitudes and frequencies. Data on the root-mean-square values of the lift and drag coefficients, the extreme values of these coefficients, and their power spectra are presented.

DIFFUSION OF A FULLY IONIZED GAS CONFINED IN A STRONG MAGNETIC FIELD. Toyoki Koga. USCEC Rep. 56-209 (AFOSR TN 59-1162), Dec. 30, 1959. 33 pp. 14 refs. Investigation of the transport phenomena of a fully ionized gas in the presence of a strong magnetic field. It is shown that there is a certain domain in the density-temperature space where the Boltzmann equation is valid. The mean free path is assumed to be longer than the mean Larmor radius. An average is made of the Boltzmann equation along a circular trajectory of gyrating particles; by this method of coarse-graining, the Boltzmann equation is reduced to that of diffusion. A special case of constant energy per particle is treated in detail. Results are compared and found similar to those obtained previously, although no specific assumption of the distribution function is made; the effect of the collisions between similar particles is negligible and the ions and electrons diffuse almost at the same velocity. The applicability of the method to more general cases is indicated.

MAGNETOHYDRODYNAMIC CHANNEL FLOW OF A PERFECT GAS FOR THE GENERATION OF ELECTRICAL POWER. G. W. Sutton. G-E MSVD AL TIS R59SD473, Dec. 8, 1959. 31 pp. Investigation considering the channel flow of an ideal, compressible, slightly ionized gas for electrical power generation. For moderate temperatures, this implies conductivities of about 1-10 mho/cm. so that the magnetic Reynolds number is small, and the externally imposed magnetic field then penetrates the gas completely. The electrical conductivity of the gas is taken as a function of temperature and pressure in accordance with well accepted theories, and the reduction in effective conductivity due to the Hall effect is considered. Analytical expressions are derived for the flow variables for flows of constant velocity, temperature, pressure, density, and area. It is concluded that, on the basis of a comparison for constant electrical conductivity, the constant velocity flow appears to be the most desirable; the length of the generator may be decreased by increasing the magnetic field or decreasing the entrance pressure. Problems due to the Hall effect can be removed almost completely by the use of segmented electrodes.

AN INVISCID BOUNDARY LAYER OF MAGNETOHYDRODYNAMICS. W. S. Lewellen. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 59-927), Sept., 1959. 46 pp. Application of a boundary-layer approximation for fluids with large electrical conductivities to the two-dimensional, steady, inviscid, incompressible magnetohydrodynamic equations for the case of a uniform magnetic field parallel to the free stream. Two approaches to the solution of the magnetic boundary layer are used. In the first, the approximate integral method is used to derive equations analogous to the von Kármán integral momentum equation of viscous theory. In the second approach, the exact magnetic-boundary-layer equations are transformed, for similar flows, into a system of ordinary differential equations. The solution of these equations is found in the form of a power-series expansion in a parameter equal to the Alfvén speed divided by the free-stream velocity. Numerical results are given for several cases of similar flow. In the sub-Alfvén flow, evidence points to a boundary layer growing in the direction opposite to the flow.

A FLIGHT INVESTIGATION INTO THE PERSISTENCE OF TRAILING VORTICES BEHIND LARGE AIRCRAFT. T. H. Kerr and F. Dee. Gt. Brit., RAE TN Aero.2649, Sept., 1959. 22 pp. Description of tests on a Devon flying in the wake of a Lincoln made in the clean and flaps-down configurations. The results indicate that the disturbance decays rapidly after 160 sec. and 105 sec., and produces negligible rolling moments after 190 sec. and 120 sec., respectively. The flight results are compared with the available theoretical data, and it is found that Squire's theory holds until the vortices start to decay rapidly.

A STUDY OF VORTEX CANCELLATION. Allan Schaffer. J. Aero/Space Sci., Mar., 1960, pp. 193-196, 233. Investigation of the cancellation of a vortex by means of another concentric vortex of equals strength but opposite spin. When such a cancellation occurs, there is a recovery of static pressure. The vortices are generated by means of two three-dimensional airfoils cantilevered from the duct wall, one being situated in the wake of the other. It is demonstrated experimentally that there exists an optimum angle of attack for the second airfoil which cancels the vortex from the first airfoil and restores uniform flow downstream of the two airfoils. A calculation of this optimum angle of attack is presented and is found to depend upon the angle of attack of the first airfoil and upon the geometrical properties of the wing. The pressure recovery accompanying the vortex cancellation is also studied.

Internal Flow

THE DRAG OF DUCTED BODIES WITH ANNULAR OR SIDE INTAKES IN SUPERSONIC FLOW. H. Portnoy. Aero. Quart., Aug., 1959, pp. 283-295. Study of a slender ducted body of arbitrary cross section having an annular or "scoop" type of intake at some streamwise station. The parts of the body forward of, and behind the, intake are permitted to have discontinuities of longitudinal profile slope at streamwise stations widely separated both from each other and from the intake. The external flow is supersonic, and it is assumed that the intake lip is sharp and that there is no "spill-over" due to choking of the internal flow. The interference drag between the forebody and the afterbody is calculated, and the results are applied to bodies of elliptic cross section.

ON AXISYMMETRICAL GAS JETS, WITH APPLICATION TO ROCKET JET FLOW FIELDS AT HIGH ALTITUDES. W. T. Lord. Gt. Brit., RAE Rep. Aero.2626, July, 1959. 37 pp. 23 refs. Study of the existing analytical, numerical, and experimental results for gas jets expanding out of

axisymmetric nozzles. Jets expanding into a vacuum and into still air at finite pressure are considered in detail and, by introducing certain new concepts, the existing results are expressed in a compact and more widely applicable form. A brief examination of jets expanding into supersonic air streams suggests that some information about the flow fields of rocket jets a high altitudes may be deduced from the extended results for still-air jets in which the reference pressure at the nozzle exit is much greater than the ambient pressure. An example for a particular rocket and a specific trajectory is given.

SKACHOK KONDENSATSII V SVERKHZVUKOVYKH SOPLAKH. A. A. Stepchkov. MVO SSSR VUZ Izv. Av. Tekh., No. 3, 1959, pp. 119-129. In Russian. Investigation covering the condensation jump in supersonic nozzles. The known equations of thermodynamics are used to determine the beginning of saturation, considered as the onset of condensation. The dependence of saturation pressure P_H from the variation of external conditions is determined from the equilibrium of the two-phase system on the basis of the Clapeyron-Clausius equation. This equation is integrated, taking into account the effect of temperature on the heat of phase transition (ℓ) and the temperature and pressure on the change of volume Δv. Thus, the dependence of saturation pressure upon temperature in the case of condensation in the neighborhood of a plane water surface is obtained. The data cover the physical process of condensation under the conditions of gas expansion in Laval nozzles and can be used in the theory of condensation under analogous conditions. The discrepancy shown by comparing theoretical and experimental data is analyzed, and tests involving the measurement of pressure distribution along the wall and the axis of a nozzle in expanding dry and humid air are described in detail.

RASPROSTRANENIE TURBULENTNOI STRUI NESZHIMAEMOI ZHIDKOSTI PO POVERKHNOSTI KONUSA. E. I. Katin. MVO SSSR VUZ Izv. Av. Tekh., No. 2, 1959, pp. 12-19. In Russian. Derivation of an analytical solution for the problem of an axisymmetric jet of incompressible fluid issuing from an orifice ($2r_0$-diam.) and propagating along the surface of a cone with a half-angle (α) at the apex. The flow ahead of the cone apex is homogeneous due to a sufficiently small distance (ℓ) between the exhaust section of the nozzle and the apex of the cone. Theoretical results are compared with experimental data, and it is found that: the flow of a gas is affected by the friction at the surface of the cone only in the layer which is adjacent to the wall and represents about 6% of the overall thickness of the jet; the relations derived assuming the absence of friction are valid outside of this layer, thus neglecting the presence of friction over the surface of the cone.

ONE DIMENSIONAL FLOW OF A GAS-PARTICLE SYSTEM. J. R. Kliegel. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-5. Members, $0.50; nonmembers, $1.00. 11 pp. Study of the one-dimensional flow of a gas-particle system and presentation of a family of solutions to the equations governing these flows. If the particles do not undergo a phase change (solidification), then the solutions for the one-dimensional flow of a perfect gas are identical to the above family of solutions provided that a suitably modified Mach number and specific heat ratio are chosen. It is shown that these solutions correspond to flow in a nozzle in which the axial velocity gradient is constant. The design of a nozzle for use with a gas-particle exhaust is discussed, and the nozzle throat region is shown to be the critical region in the design of such a nozzle. It is further shown that the nozzle throat conditions depend on the particle kinetic and thermal lags at the throat, and hence, on the nozzle inlet geometry. Relationships between the nozzle throat geometry and the particle lags in the throat region are given for both two-dimensional and axially symmetric nozzles.

Jet Flaps & Wings

THE FINITE ASPECT RATIO JET FLAP. R. A. Hartunian. Cornell Aero. Lab. Rep. AI-1190-A-3, Oct., 1959. 70 pp. 28 refs. Army-sponsored derivation of lifting surface equations for the finite aspect ratio wing equipped with jet flaps, assuming small perturbations of the undisturbed flow. The limiting case of large aspect ratio is considered in detail; the resulting equations are solved for the special case of a system with elliptic loading. Relations for the lift coefficient, jet shape, and pitching moment are presented. The results of the theory are found to be in good agreement with experiment over a wide range of aspect ratios, angles of attack, jet deflections, and jet momentum coefficients. The induced drag, obtained for the elliptically loaded case, is shown to agree with the results of a momentum theory. Comparison of the induced drag with the experimentally determined drag is also discussed.

A NOTE ON THE DRAG DUE TO LIFT AS INFLUENCED BY A JET FLAP ON A WING OF FINITE SPAN. S. B. Berndt. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 85, Sept., 1959. 10 pp. Extension of the classical theory for thin and lightly loaded wings in subsonic flow, considering the interaction between the jet and the trailing vortices. It is shown that for given lift, span, and jet thrust the minimum induced drag is reduced by a jet flap, the reduction corresponding to an increment of $2C_J/\pi$ to the aspect ratio (C_J being the jet coefficient, referred to free-stream dynamic pressure and wing area). It is also stated that the minimum drag is obtained when the downwash angle at the trailing sheet far downstream is constant throughout the span, and that the minimum drag is half the product of the lift and this downwash angle.

Stability & Control

COMPARISON OF SOME EXPERIMENTAL AND THEORETICAL DATA ON DAMPING-IN-ROLL OF A DELTA-WING BODY CONFIGURATION AT

SUPERSONIC SPEEDS. L. T. Conlin and K. J. Orlik-Rückemann. Canada, NRC Aero. Rep. LR-266, Dec., 1959. 16 pp. Description of tests on a wing-body combination consisting of a triangular wing of aspect ratio 2 and a body of revolution, with and without fins. The free oscillation technique is used to measure the damping-in-roll derivative at two oscillation frequencies. Results are compared with theory and other wind-tunnel and aeroballistic-range experiments. The damping-in-roll derivative ($-C_{l_p}$) is found to decrease with increasing supersonic Mach number and increase with increasing frequency.

DEVELOPMENT OF LATERAL-DIRECTIONAL FLYING QUALITIES CRITERIA FOR SUPERSONIC VEHICLES, BASED ON A STATIONARY FLIGHT SIMULATOR STUDY. R. M. Crone and R. C. A'Harrah. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-18. Members, $0.50; nonmembers, $1.00. 15 pp. 14 refs. Study indicating that a modification to the present military specifications for the lateral-directional oscillatory characteristics would be desirable for the high-speed, high-altitude flight region. A proposed criterion is formulated for the specification of satisfactory lateral handling qualities, on the basis of a parameter which successfully correlates pilot opinion rating of the lateral handling qualities. A comparison is made of these results with other pilot evaluation studies which utilized variable stability aircraft.

Wings & Airfoils

CALCULATION OF AERODYNAMIC LOADING AND TWIST CHARACTERISTICS OF A FLEXIBLE WING AT MACH NUMBERS APPROACHING 1.0 AND COMPARISON WITH EXPERIMENT. Appendix - RELATIONS USED TO CALCULATE DOWNWASH. J. P. Mugler, Jr. US, NASA TR R-58, 1960. 30 pp. Presentation of an iteration method applicable to the calculation of flexible wings with known elastic properties at Mach numbers approaching 1.0, as well as at subsonic Mach numbers. Calculations are made for a combination of a body and a cambered wing with 45° sweepback, an aspect ratio of 4, a taper ratio of 0.15, and a thickened root section. Comparisons of experimental and calculated results at Mach numbers from 0.80 to 0.98 indicate that: (a) at a Mach number of 0.80, the calculated and experimental loadings and the wing twist distributions are in good agreement from 0° to 4° angle of attack; at higher positive angles and at negative angles, the experimental data indicate that separation is prominent on the wing and the agreement between calculated and experimental results is poor; (b) with increasing Mach number, the agreement at 2° and 4° angle of attack becomes increasingly poorer, but is still good at 0° angle of attack at a Mach number of 0.98. The experimental data indicate that the poorer agreement at angles of attack of 2° and 4° for the higher Mach number is the result of large regions of mixed flow which developed on the wing.

K RASCHETU PROCHNOSTI UPRUGOGO MONOLITNOGO KRYLA. M. B. Vakhitov. MVO SSSR VUZ Izv. Av. Tekh., No. 3, 1959, pp. 24-32. In Russian. Study of the thin elastic monolithic wing having a thick skin reinforced by stiffening ribs in the direction of the axes $o\eta$ and $o\xi$. A cantilever anisotropic plate is used as the representative model. The mass loading is taken into account, and the two specific cases considered are: (a) a given angle of attack of the root section and (b) a given load coefficient n, representing the effect of turbulence and curvilinear flight along a given trajectory, respectively. The study is based on a statistical approach - i.e., it is assumed that equilibrium is reached in the process of varying wing deformation and the related variation of external forces. The derived formulas are also used to determine the critical rate of wing divergence and aileron reversal.

SUPERSONIC ESTIMATION OF THE WING INCIDENCE EQUIVALENT TO A CAMBER DISTRIBUTION. L. M. Sheppard. Australia, WRE TN HSA 53, Oct., 1959. 8 pp. Application of the two-dimensional supersonic airfoil theory to determine the lift increment associated with a camber distribution. This lift increment is found to be proportional to the product of camber and thickness ratios. The equivalent wing incidence, giving the same lift increment, can be calculated directly from the lift curve slope. Results are given for some simple camber and thickness distributions of the double-wedge, modified double-wedge, and parabolic-arc types. Estimates of equivalent wing incidences, which follow from such results by using a strip method, are applicable to stabilizing fins of test vehicles when rolling frequencies have to be predicted.

O NEUSTANOVIVSHEMSIA DVIZHENII KRYLA PRIAMOUGOL'NOI FORMY V PLANE. V. A. Kovaleva. Prikl. Mat. i Mekh., Nov.-Dec., 1959, pp. 1030-1041. In Russian. Presentation of results on the unsteady motion of thin rigid wings of finite span and rectangular plan form in supersonic flow, arbitrarily varying with time, including the gust or shock-wave dependent unsteady motion. The problem is treated linearly, and a solution is obtained for the case of a time-dependent variation in angle of attack; the partial solution is used to study the case of an angle of attack arbitrarily varying with time. The problem of a wing of rectangular plan form is solved by taking into account the edge effects.

K TEORII KOL'TSEVOGO KRYLA V SVERKHZVUKOVOM POTOKE. G. E. Bobrov. MVO SSSR VUZ Izv. Av. Tekh., No. 3, 1959, pp. 3-8. In Russian. Study of the theory of annular wings. A solution for the problem of lifting force and aerodynamic moment, depending upon the pressure of the supersonic flow over the internal surface of the wing, is derived within the limits of the linear theory. The flow around the wing is assumed to be steady, nonviscous, adiabatic, and irrotational; and the profile of the wing, the angle of attack, as well as the Mach number of the undisturbed flow correspond to the assumptions of the linear supersonic flow theory. The study is simplified by

limiting the calculation to cylindrical annular wing profiles of zero thickness. Due to the supersonic character of the flow, the presence of a vortex layer behind the wing could be neglected and replaced by a solid cylindrical surface representing an extension of the wing.

ON THE AERODYNAMIC DESIGN OF SLENDER WINGS. E. C. Maskell and J. Weber. RAeS J., Dec., 1959, pp. 709-721. 19 refs. Analysis considering the design of slender pointed wings with sharp edges, under the condition that flow separation from these edges shall dominate the flow pattern in all flight attitudes. It is concluded that if the leading edge separations are to develop regularly with change of attitude of the wing, separation must occur only from the trailing edge at the design attitude. Subject to these restrictions, low drag is sought at the design attitude. This leads to the consideration of a particular class of doubly curved mean surfaces satisfying the leading edge condition, onto which thickness distributions are superposed so as to provide favorable velocity fields together with low drag. A number of examples are considered to illustrate the manner in which plan form and thickness distributions affect the pressure distribution, and to indicate the relatively high lift/drag ratios which seem feasible.

NOTES ON THIN WING THEORY AT LOW SUPERSONIC SPEEDS. I - THE DESIGN OF LIFTING SURFACES. G. J. Hancock. Aero. Quart., Aug., 1959, pp. 247-265. Development of a numerical method, based on linearized theory, for establishing the integral relationship for the incidence distribution in terms of the velocity potential for wings with subsonic leading edges. Three examples with various edge singularities that may be encountered in practice are studied, and it is shown that, with a fairly wide mesh distribution, errors are appreciable only for the edge areas of the mesh. Two ways of avoiding these errors are discussed: (a) extrapolation of incidence values calculated at the inboard area, and (b) decreasing the mesh areas locally in the edge regions and thus approaching the conditions at these edges more accurately.

NOTES ON THIN WING THEORY AT LOW SUPERSONIC SPEEDS. II - A UNIFIED NUMERICAL METHOD FOR THE CALCULATION OF THE LOADING ON WINGS WITH SUBSONIC LEADING EDGES. G. J. Hancock. Aero. Quart., Nov., 1959, pp. 319-325. Presentation of a numerical method for lifting problems that are completely general, for wings with subsonic leading edges having any camber and trailing edge conditions. The incidence distribution, given at a series of discrete points on the wing surface, is specified in terms of the discontinuity in the velocity potential, also at a series of discrete points, so that there is a matrix equation between these two functions. The inversion of the influencing matrix leads to the determination of an unknown velocity potential distribution from a known incidence distribution.

EXPERIMENTAL INVESTIGATION ON DELTA WING AND COMPLETE CONFIGURATION MODELS FOR AEROELASTIC SIMILARITY PROBLEMS AT SUPERSONIC BLOW DOWN WIND-TUNNEL. Appendix - THE MAGNETIC SUPPORT. Luigi Broglio, Carlo Buongiorno, Ugo Ponzi, and Giorgio Ravelli. Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 50 (AFOSR TN 59-954), Mar., 1959. 63 pp. Presentation of experimental techniques and wind-tunnel data obtained at a Mach number of 3.01 on triangular wing models. The results define the importance of the chordwise deflection of the section on the aerodynamic characteristics. An experimental investigation made on a complete aircraft configuration at a Mach number of 3.12 is described, showing the importance of the parameter p_o/E on the lateral stability derivatives. The preliminary study covering the design of a magnetic support for dynamic stability tests is also included.

SOME FREE FLIGHT TESTS ON THE SONIC AREA RULE AND WING-BODY WAVE DRAG. L. M. Sheppard. Australia, WRE TN HSA 51, June, 1959. 29 pp. Presentation of results for a program of free-flight tests covering the zero-lift wave drag of wings and equivalent bodies having the same cross-sectional area distributions, as well as the effect on wave drag of the body cross-sectional shape. When the wing has a round-nosed RAE 104 section it has a higher transonic drag-rise than its equivalent body. Thus, there appears to exist a leading edge drag force varying with Mach number. Results show that body cross-sectional shape does not influence the drag rise unless it is extreme, with high local surface slopes.

O TELAKH MINIMAL'NOGO VOLNOVOGO SOPROTIVLENIIA. V. N. Zhigulev and Iu. L. Zhilin. Prikl. Mat. i Mekh., Nov.-Dec., 1959, pp. 1019-1029. In Russian. Investigation of some variational problems for bodies with minimum drag at supersonic velocities. To illustrate the solution, a relationship is established which relates the value of the body value to the values of the turbulent velocity potential over the characteristic surface bounding the body. The problem of selecting the optimum fuselage configuration of given length and volume is analyzed along with that of drag of a wing-body system. Also covered are the cases of extremal bodies and bodies of revolution with cylindrical flows.

AEROELASTICITY

DYNAMIC AIRLOADS AND AEROELASTIC PROBLEMS AT ENTRY MACH NUMBERS. G. Zartarian, P. T. Hsu, and H. Ashley. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-32. Members, $0.50; nonmembers, $1.00. 31 pp. 42 refs. USAF-supported presentation of two approximate techniques for predicting dynamic airloads. For low to moderate values of the parameter $M_\infty \tau$, a variational principle is used in conjunction with hypersonic small-disturbance theory (thickness ratio $\tau << 1$) to find the pressure distribution due to a steady or arbitrarily

time-dependent motion. The key step is the reduction to a series of equivalent two-dimensional piston problems, which are solved by the Ritz method. At higher values of $M_\infty \tau$, a simple extension of shock-expansion theory, also relying on the piston analogy, appears to furnish a rational approximation for many configurations. It consists of determining flow parameters just aft of the nose shocks, then carrying out a Prandtl-Meyer expansion along surface streamlines in planes normal to the body. The two methods are applied to static divergence of a cantilevered ogive of revolution.

APPROXIMATE ANALYSIS OF BODY FLUTTER OF ROCKETS. I, II. Ken Ikeda. Japan Soc. Aero. & Space Sci. J., Sept.; Oct., 1959, pp. 1-16; 1-5. 42 refs. In Japanese. Analysis considering the phenomenon as a critical motion of the bending vibration combined with (a) pitching and (b) pitching and bouncing. Two models are proposed to obtain an estimate of the effect of design factors on the critical speed. The first has two massless rigid bars that are connected at their ends by an elastic spring, and each bar has an attached concentrated mass at an appropriate position. The spring masses and their positions are adjusted so that the model and actual missile have the same natural bending frequency, equal total weight, and equal moment of inertia. The center of gravity of the model before the bending deformation is assumed in the first case to be fixed on the flight path even during the oscillation to neglect the effect of bouncing. In the second case, the model is the same except for another concentrated mass attached at the center of gravity to account for the effects of bouncing. Simple formulas are then derived to estimate the critical flutter speed, and the design parameters effecting the flutter are discussed.

FLEXURAL VIBRATIONS OF A RECTANGULAR SANDWICH PANEL. C. C. Chang and B. T. Fang. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-21. Members, $0.50; nonmembers, $1.00. 19 pp. USAF-sponsored derivation of differential equations and boundary conditions by taking into account the rotational inertia of the whole panel, the shearing deformation, and the viscoelastic damping of the core. The dynamic response of a simply-supported rectangular panel to a unit step function is first obtained, and the general transient and steady-state response of the panel to an arbitrary input function is then expressed in terms of the unit response by means of the convolution integral. It is shown that three families of modal shapes of vibration are possible for each nodal pattern of the panel. The frequencies and amplitudes of vibration of these three modes are discussed in detail for the case of an isotropic and elastic snadwich panel.

KOLEBANIIA KRYLA MALOGO UDLINENIIA V DOZVUKOVOM POTOKE. T. K. Sirazetdinov. MVO SSSR VUZ Izv. Av. Tekh., No. 3, 1959, pp. 16-23. In Russian. Derivation of an integral differential equation for a wing oscillating in a subsonic flow, and presentation of an approximate method for the case of small aspect-ratio wings. The study is made under the assumption of a thin wing and small values of vibration and deformation, as well as of their frequency. Formulas are derived for the lifting force and moment of the wing section. The effect of profile thickness on pressure distribution over the oscillating wing is also calculated.

THE EFFECT OF AN EXTERNAL SUPERSONIC FLOW ON THE VIBRATION CHARACTERISTICS OF THIN CYLINDRICAL SHELLS. H. M. Voss. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-45. Members, $0.50; nonmembers, $1.00. 23 pp. 16 refs. Analysis of the effects of curvature on panel flutter. The problem is first defined on the basis of Reissner's shallow cylindrical shell vibration theory and piston theory air forces. The nature of the solution and its critical dependence on frequency are illustrated by a simple two-mode solution. The complexity of the frequency spectrum previously noted by several authors is emphasized in the inability to choose modes of maximum coupling, as is commonly done in other aeroelastic problems. Based on these results, the problem is recast in terms of the zero-air-speed frequencies. The solution is then outlined in terms of Gol'denveizer's equations for thin cylindrical shells, including mid-plane inertia, and determination of frequencies and damping of the modes as a function of the aerodynamic parameters.

FUELS & LUBRICANTS

CRYOGENIC PROPELLANT STORAGE FOR ROUND TRIPS TO MARS AND VENUS. G. R. Smolak and R. H. Knoll. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-23. Members, $0.50; nonmembers, $1.00. 23 pp. 14 refs. Study of sources of cryogenic propellant heating and methods for minimizing resultant vaporization losses. It is shown that propellant losses can be minimized by using thermal radiation shielding and by optimizing both stage orientation with respect to the Sun and tankage arrangement. Storage of cryogenics for several trips to Mars and Venus (including parking time in orbit) is found to be feasible using these thermal protection devices. Propellant vaporization losses for each phase of these trips are discussed.

MATERIALS

High Temperature

THE PERFORMANCE OF ABLATION MATERIALS AS HEAT PROTECTION FOR RE-ENTERING SATELLITES. W. R. Warren and N. S. Diaconis. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-49. Members, $0.50; nonmembers, $1.00. 44 pp. 15 refs. USAF-sponsored discussion of probable advantages to be derived through the use of an ablation system for the heat protection of re-entering satellite vehicles. Results from experimental studies of three ablation materials - teflon, a phenolic resin reinforced with nylon, and a foamed polyurethane plastic - are presented and discussed. Experiments were run at two body stations, the stagnation

region and the skirt region; and three types of experimental data are presented - insulated backwall temperatures, surface temperatures, and total mass losses. Experimental and theoretical verifications are given for the assumption that satisfactory simulation of a variable heating history can be obtained through the use of constant test conditions.

Metals & Alloys

BRITTLE FRACTURE AND THE YIELD POINT PHENOMENON. N. Louat and H. L. Wain. Australia, ARL Rep. Met. 32, Apr., 1959. 37 pp. 47 refs. Further development of the modified theory on Cottrell-locking, including quantitative and qualitative comparison with experiment. A simple inversion of the equation relating yield point to testing temperature leads to a condition for brittle fracture which is examined in the light of recent experimental work, particularly on iron, steel, molybdenum, and chromium. Theoretical predictions on the grain size, loading rate, work hardening, and variations in yield strength on the ductile-brittle transition temperature are shown to agree with experiment.

MECHANICS

SLOSHING OF LIQUIDS IN CIRCULAR CANALS AND SPHERICAL TANKS. Bernard Budiansky. J. Aero/Space Sci., Mar., 1960, pp. 161-173. USAF-supported calculation of the natural modes and frequencies of small-amplitude sloshing of liquids in partially filled tanks. An integral-equation approach is used to analyze the circular canal for arbitrary depth of liquid. A similar approach for the spherical tank provides modes and frequencies for the nearly full and half full cases. These results, together with the known behavior of the nearly empty tank, are used in conjunction with the trends established for the circular canal as a basis for estimating frequencies for arbitrary depth of liquid in the spherical tank. The dynamic analysis of the container-fluid system by means of the mode-superposition approach is discussed, and modal parameters required in such analyses are presented.

MISSILE, ROCKET, & SPACE TECHNOLOGY

SPECIAL ISSUE: A DISCUSSION ON SPACE RESEARCH. Royal Soc. (London) Proc., Ser. A, Dec. 29, 1959, pp. 450-541. 212 refs. Partial Contents: Some Problems Concerning the Terrestrial Atmosphere Above About the 100 km Level, D. R. Bates. Interplanetary Space and the Earth's Outermost Atmosphere, S. Chapman. Experiments on Cosmic Radiation by Means of Artificial Satellites, C. F. Powell. Space Research in Relation to the Moon and the Nearer Planets, T. Gold. Astronomical Observation with the Aid of Artificial Satellites, F. Hoyle. Radio Astronomical Measurements from Earth Satellites, A. C. B. Lovell. Performance, Control and Guidance of Satellite Vehicles, A. W. Lines. Radio Communication with a Lunar Probe, W. T. Blackband. Some Techniques of Physical Measurement, R. L. F. Boyd. Self-Contained Measuring Equipment for Electron Density and Ionic Mass Spectrum, J. Sayers. Analysis of the Orbits of the Russian Satellites, D. G. King-Hele. Survey of the state of knowledge on the different phenomena which are most susceptible to study by means of instrumented satellites or space probes. Included are problems of lunar, solar, and planetary physics. Some of the limitations imposed by the requirements of the guidance, control, and tracking of space vehicles, and of recovering data from them are considered. This is followed by a description of some instruments suitable for use within such vehicles. Some results are given from the analysis of the data obtained in the orbit of the satellites and from measurements made with the instruments contained within them.

STRUCTURAL CONSIDERATIONS OF MANNED SPACE VEHICLES. A. P. Coppa. (ARS 13th Annual Meeting, New York, Nov. 17-21, 1958.) ARS J., Jan., 1960, pp. 34-40. Discussion of approaches leading to an optimum vehicle considering the requirements of thermodynamics and human factors, in addition to structures. The necessity of early and thorough integration of these different requirements is emphasized. Several space vehicle configurations are presented, including a ballistic and a glide type, in order to exemplify some of the various structural problems encountered in each type during the phases of spaceflight, entry into an atmosphere, and landing. These include aerodynamic heating and loading, meteoroid impact, and other problems. Materials and constructions suitable for optimum space structures are discussed.

A NOVEL SYSTEM FOR SPACE FLIGHT USING A PROPULSIVE FLUID ACCUMULATOR. S. T. Demetriades. (Northrop ND Rep. NB-59-161, Dec. 20, 1958.) Brit. Interpl. Soc. J., Sept.-Oct., 1959, pp. 114-119. Description of a propulsion system for spaceflight which can bring about significant decreases in the required take-off mass by collecting and storing gases in the upper atmosphere of a planet and by using these gases as a propulsive fluid in conjunction with a power source.

EQUATIONS OF MOTION OF A MISSILE. Toyoshi Morozumi. Nihon U. Res. Inst. Tech. J., Oct., 1959, pp. 27-31. In Japanese. Study considering the missile as a rigid body having a moving coordinate system that is relative to a fixed coordinate system in space. General equations of motion are derived which take into account the variation of mass due to the high rate of fuel consumption. Although direct solutions are extremely difficult, simplified equations can be derived from the above for cases of certain motions.

Ballistics, Re-Entry

AN APPROXIMATION TO THE RE-ENTRY TRAJECTORY. M. M. Moe. ARS J., Jan., 1960, pp. 50-53. Presentation of an approximation which includes the effects of both air resistance and

gravity on the re-entry trajectory. An integral equation is written for the trajectory angle and the re-entry angle is used as a trial solution. The integrals can be evaluated if a constant drag coefficient and exponential atmospheric density are assumed. The approximation is good if the re-entry angle is greater than 5° and if the trajectory angle does not change greatly. Results for a wide range of weight-to-drag ratios and initial conditions are compared with exact solutions.

ORBITAL ELEMENTS, TRAJECTORY SIMULATION, AND PREDICTION FOR EARTH SATELLITES. A. D. Wasel. (Lockheed Aircraft Missile Systems Div. Rep. LMSD-5026, June 25, 1958.) Brit. Interpl. Soc. J., Sept.-Oct., 1959, pp. 130-133. Presentation of the so-called orbital elements and indication of their notation. The forms of the equations of motion resulting from several different approaches are shown, and a trajectory simulation utilizing statistical methods is described. Several examples of possible techniques for determining values of orbital elements for prediction purposes are detailed. Finally, combinations of various kinds of tracking data are listed.

Guidance, Control, Stability

MIDCOURSE GUIDANCE PROBLEM IN SATELLITE INTERCEPTION. I. A. J. Skalafuris and D. H. Schiller. ARS J., Jan., 1960, pp. 41-46. USAF-sponsored analysis of the midcourse guidance problem considering only two-dimensional geometry and circular target orbits. Equations are developed yielding the required velocity corrections necessary for interception as a function of the rocket's present position and velocity, relative to the target. Velocity corrections for different types of interception (minimum landing power, minimum midcourse power) are considered.

MISSILE ORIENTATION ERRORS IN COMMAND GUIDANCE SYSTEMS. K. C. Mathews. ARS J., Jan., 1960, pp. 46-50. Analysis of command errors and performance degradation resulting from tracker errors and angles of attack in two types of command guidance systems employing the roll autopilot control equation for orientation computations. It is shown that much smaller com mand errors are expected to occur in a system in which the roll autopilot keeps the time integral of roll rate equal to zero, than in a system in which the roll autopilot maintains perpendicularity between one wing plane and a fixed inertial reference plane.

A STUDY OF THE GUIDANCE OF A SPACE VEHICLE RETURNING TO A BRAKING ELLIPSE ABOUT THE EARTH. J. A. White. US, NASA TN D-191, Jan., 1960. 65 pp. Analysis assuming random errors in the measurement of velocity and flight-path angle and in obtaining the desired thrust impulse. Three methods for scheduling and applying corrective impulses are investigated on the basis of efficiency and accuracy. The first method scheduled thrust corrections as a function of the radial distance from the vehicle to the center of the earth; the second method scheduled the corrections as a function of flight time; and the third, as a function of the angle between perigee and the vehicle position vector. The third method appears to provide the best perigee altitude control. For the three methods studied, an error in the flight-path angle had a predominant effect over errors in velocity and thrust impulse. It was found that, although the trajectory was changed at each point of correction, the radial distance and the instrumentation accuracy at the final correction point before perigee determined the first-pass perigee altitude.

Spacecraft

THE CALCULATION OF MINIMAL ORBITS. G. C. Smith. Astronautica Acta, Fasc. 5, 1959, pp. 253-265. Derivation of solutions for the equations determining the mode of transfer of a rocket between two coplanar orbits with minimal fuel expenditure, for a number of different cases. Proof is included that a cotangential ellipse is a first-order approximation to the minimal mode of transfer between two orbits of small eccentricity.

THE THREE-BODY PROBLEM EARTH - MOON - SPACESHIP. W. Gröbner and F. Cap. (10th Internatl. Astron. Congr., London, Aug. 31-Sept. 5, 1959.) Astronautica Acta, Fasc. 5, 1959, pp. 287-312. Derivation of a solution of the astronomical n-body problem using Lie series. First, the solutions of the two-body problem are discussed, and then the solution of the three-body problem is given in which a decomposition of the Lie operator is useful. Two different numerical methods of computation are outlined.

A GENERALIZATION OF THE MINIMUM IMPULSE THEOREM TO THE RESTRICTED THREE-BODY PROBLEM. L. G. Vargo. Brit. Interpl. Soc. J., Sept.-Oct., 1959, pp. 124-126. Establishment of a relation between the path variables in the restricted three-body problem which minimizes the velocity addition required to cause a given change in the value of the Jacobi integral. The result is compared to the classical two-body case and applied to a lunar orbit problem of practical significance. The theorem is shown to be useful as a means of analyzing the complex interaction of propulsion requirements and three-body trajectories.

ORBITS OF COSMIC ROCKETS TOWARD THE MOON. L. I. Sedov. (ARS Annual Meeting, Wash., Nov. 17, 1959.) ARS J., Jan., 1960, pp. 14-21. Discussion of the fundamentals of space flight, including the basic requirements of propulsion, guidance, and take-off conditions. The collision case is considered, and the properties of a set of trajectories, sufficiently accurate for use in the solution of some practical problems, are listed. Available data on the orbits of the three Soviet cosmic rockets are also given.

POWER PLANTS

EXPERIMENTAL INVESTIGATIONS OF PLASMA ACCELERATORS FOR SPACE VEHICLE GUIDANCE AND PROPULSION. B. Gorowitz, K. Moses, and P. Gloersen. (4th Ballistic Missiles & Space Tech. Symposium, Los Angeles, Aug. 26, 1959.) G-E MSVD AL TIS R59SD466, Nov. 23, 1959. 24 pp. Description of studies concerning the possible application of a pulsed plasma acceleration device for space propulsion and attitude control. The laboratory model uses an electric discharge to create a plasma which is electromagnetically accelerated into a high vacuum chamber. A valve is devised which serves the dual purpose of introducing the minute amounts of propellant required while obviating the need for external switching of the discharge. Specific impulses obtained with the accelerator are in the range of 1,000-20,000 sec. Measurements indicate efficiency of conversion of stored electrical energy to mechanical energy up to 60%.

UBER DAS RICHTEN INTERSIVER PHOTONENSTRAHLEN MITTELS ELEKTRONENGASSPIEGEL. Eugen Sänger. (10th Internatl. Astron. Congr., London, Aug. 31-Sept. 5, 1959.) Astronautica Acta, Fasc. 5, 1959, pp. 266-286. 30 refs. In German. Study on the direction of intense photonic beams by electron gas mirrors. Radiation intensities of roughly 10^9 cal./cm^2 sec., as required for photonic propulsive jets, can be realized through black radiation of heavy plasmas of 150,000°K. To direct in parallel and to focus this radiation, reflection degrees of at least $1\text{-}10^{-6}$ within the wave length range between 10^{-7} and 10^{-4} cm. are required of the reflectors. To realize the electron densities of roughly 10^{27} cm.$^{-3}$ required for mirrors of such a reflective power, heavy compression shocks of plasma and/or compression shocks of pure electron gas are recommended.

Jet & Turbine

SCALE EFFECT ON WALL TEMPERATURE IN A GAS TURBINE SPRAY COMBUSTION CHAMBER. M. V. Herbert and J. A. Bamford. Gt. Brit., NGTE Memo. M.326, Oct., 1959. 19 pp. Description of measurements of primary zone wall temperatures on two aircraft pattern combustion chambers with a scale ratio of 2. An analysis of the heat transfer process with respect to linear scale and pressure enables trends to be established over a wide range of conditions. It is shown that the established scaling technique - in which pressure is varied inversely as linear scale, and gas temperatures and velocities are kept constant - does not give exact similarity in wall temperatures. The discrepancy is, however, much less than would result from holding the pressure constant with a varying scale.

Rocket

CHEMICAL NONEQUILIBRIUM EFFECTS ON HYDROGEN ROCKET IMPULSE AT LOW PRESSURES. J. G. Hall, A. Q. Eschenroeder, and T. J. Klein. Cornell Aero. Lab. Rep. AD-1118-A-8 (AFOSR TN 59-1192), Nov., 1959. 10 pp. Description of calculations of nonequilibrium hydrogen flows for a lower range of pressures, as well as a wider range of temperatures and nozzle geometry, than previously considered. An approximate method of analysis is used, involving a local relaxation length criterion for determining the freezing of gas composition, the criterion being evaluated on the basis of corresponding equilibrium flow solutions. Comparisons with exact numerical solutions show the criterion to give an accurate prediction of the frozen dissociation level.

STUDIES OF CHEMICAL NONEQUILIBRIUM IN HYPERSONIC NOZZLE FLOWS. Appendix - ASYMPTOTIC SERIES SOLUTION FOR LARGE AREA. J. G. Hall and A. L. Russo. Cornell Aero. Lab. Rep. AD-1118-A-6 (AFOSR TN 59-1090), Nov., 1959. 59 pp. 20 refs. Description of analyses made of chemical nonequilibrium effects in pseudo-one-dimensional nozzle flows where the working fluid is a mixture of a dissociating species and inert diluent. Numerical examples computed on a high-speed digital machine are given for the critical flow of pure oxygen at a reservoir temperature of 5,900°K. over a wide range of reservoir pressures. The characteristic feature of all solutions is discussed, and approximate methods are given for analyzing such flows on the basis of infinite reaction-rate solutions. Applications are made to nonequilibrium airflow in hypersonic wind tunnel nozzles and to nonequilibrium hydrogen flow at conditions relevant to space-flight propulsion. It is found that high reservoir pressures are essential to avoid significant nonequilibrium effects in hypersonic wind tunnel test flows of air and in rocket nozzle flows using hydrogen-like propellants. For the rocket nozzle, the net effect of nonequilibrium is to make the specific impulse for infinite expansion ratio only weakly dependent on chamber pressure for a given chamber temperature.

EXPERIMENTAL INVESTIGATION IN AN ALTITUDE TEST FACILITY OF BURNING OF EXCESS COMBUSTIBLES IN A ROCKET ENGINE EXHAUST. H. E. Bloomer, P. E. Renas, and R. J. Antl. US, NASA TN D-200, Jan., 1960. 25 pp. Description of experiments on a 333-lbs.-thrust rocket engine using JP-4 fuel and gaseous oxygen as propellants. Four afterburning configurations using bypass air as the oxidant and one using gaseous oxygen were tested. Gas samples were obtained from the rocket exhaust over the following ranges of variables: altitude pressure of 1-10 lbs. per sq. in., and rocket oxidant-fuel ratio of 1.80-3.20. Results show that combustibles can be burned over a range of variables covered, within a length of 38 rocket nozzle exit diameters. Burning these combustibles becomes easier as: (a) ambient pressure becomes higher; (b) excess air or oxygen (beyond air stoichiometric) is added; (c) more length is allowed for combustion; and (d) the air or oxygen is directed into the rocket exhaust rather than mixing unassisted.

CONSIDERATIONS IN THE DESIGN OF CHEMICAL ROCKET POWERPLANTS FOR SPACE AP-

PLICATIONS. Stanley Lehrer. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-24. Members, $0.50; nonmembers, $1.00. 23 pp. Study of high-performance space rocket power plants that are capable of being throttled and refired. Because of the zero ambient pressure, modifications are required to a number of normal performance, cooling, and hardware concepts on which earthbound powerplants are judged. Some of the factors considered include the following: (1) selection of engine type and basic design, (2) selection of propellants, (3) multiple start-shutdown capability, (4) throttling schemes - as related to performance and cooling, and (5) environmental factors. Other pertinent considerations include the use of advanced high temperature materials and lightweight corrugated or other composite constructions, suitability for manned application, optimum propellant tank pressurization techniques, and power-plant installation considerations.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

INTERFERENCE ON A THREE-DIMENSIONAL JET-FLAP WING IN A CLOSED WIND TUNNEL. E. C. Maskell. Gt. Brit., RAE TN Aero. 2650, Aug., 1959. 18 pp. Extension of the classical theory of wind-tunnel interference to cover the case of a full-span jet flap at the trailing edge of a high aspect ratio unswept wing. It is shown that, for small constraint, corrections ΔC_J and $\Delta \alpha$ must be added to the observed jet momentum coefficient and wing incidence, respectively. These corrections are derived together with the corresponding corrections to the observed lift and thrust coefficients. Corrections to the observed downwash field over a limited interval downstream of the trailing edge of the wing are also derived. These lead to a corrected jet path and a downward displacement of the downwash pattern, in addition to the direct increment to the observed downwash. Corresponding corrections to tail height and setting are also given.

QUASI-STEADY DERIVATIVES FOR THE SUBSONIC FLOW PAST AN OSCILLATING AEROFOIL IN A POROUS WIND TUNNEL. D. G. Drake. Aero. Quart., Aug., 1959, pp. 211-229. Investigation of compressible subsonic flow about an oscillating, two-dimensional airfoil between porous walls, and development of aerodynamic derivatives for pitching motion about the mid-chord of the airfoil. The expressions for the derivatives include as special cases those of the closed tunnel and the open jet, corresponding to zero and infinite porosity, respectively. The possibility of eliminating and reducing the interference effects of the tunnel walls on the lift and moment forces acting upon the airfoil is also discussed.

ROTATING WING AIRCRAFT, HELICOPTERS

SOME DESIGN ASPECTS OF TANDEM ROTOR HELICOPTERS. I, II. J. D. Sibley and C. H. Jones. (Helicopter Assn. Gt. Brit. Meeting, London, June 5, 1959.) Helicopter Assn. Gt. Brit. J., Oct., 1959, pp. 225-251; Discussion, pp. 252-261. 13 refs. Discussion of aerodynamic and dynamic aspects in the development of Bristol tandem helicopters. Significant factors in performance, control, and stability are presented. In addition, design aspects of a proposed tandem helicopter using a wing to off-load the rotor at high speeds are presented. Some of the dynamics problems examined are those of the transmission and engine control, undercarriage and ground resonance, and the effect of the flying control circuit on blade flutter and forced vibration.

AERODYNAMIC PARAMETERS SELECTION IN HELICOPTER DESIGN. I. A. Sikorsky. (4th Internatl. Aero. Congr. on Rotary Wings & Vertical Flight, Paris, June 15-19, 1959.) AHS J., Jan., 1960, pp. 41-60. 61 refs. Presentation of fundamental equations and charts for selecting major aerodynamic parameters and showing the fundamental relationship between these parameters. Aerodynamic considerations are examined in hovering and vertical flight with formulas and charts for preliminary estimation of thrust and power required. Selections of diameter, solidity ratio, and tip speed are also included. The determination of hovering ceiling and approximate maximum thrust capacity of the rotor is also treated. Aerodynamic considerations in forward flight are examined to show the importance of high cruising speed in the economics and in the competitive ability of the helicopter. Determination of approximate capacity of the rotor and absolute ceiling is included. The limitations imposed by stall and compressibility in hovering, vertical climb, and forward speed are shown along with the limitations due to weight, size, and economic considerations. The conclusion is that the requirements for efficient and smooth operation at high speed conflict with hovering requirements, that aerodynamic efficiency conflicts with structural efficiency, size, and weight limitation, so that a design compromise must be achieved.

SOME OBSERVATIONS ON THE DYNAMIC BEHAVIOR OF EXTREMELY FLEXIBLE ROTOR BLADES. R. L. Goldman. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-44. Members, $0.50; nonmembers, $1.00. 15 pp. Study of dynamic stability problems for flexible, light-weight rotor blades with low disc loadings, whose rigidity is maintained not by the structure but by the centrifugal stiffening effects associated with a rotating system. It is shown theoretically that the flutter and divergence boundaries for this blade are virtually independent of rotor speed, while the location of the elastic axis is the major dynamic stability parameter. The analytical results are substantiated by correlation with the results of a test program using a dynamically scaled model rotor blade.

DYNAMIC ABSORBERS IN THE ROTATING SYSTEM OF HELICOPTERS. R. R. Lynn. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-28. Members, $0.50; nonmembers,

$1.00. 17 pp. Summary of recent investigations of vertical and in-plane dynamic absorbers in the rotating system. Results show that rotating absorbers can significantly alter the response characteristics of a rotor system. The inherent damping of that system is shown to be an important factor in defining these response characteristics. In many cases, important reductions in rotor stresses and/or pylon vibrations can be obtained by the use of such a device. It is shown that these results may be predicted by a simple nonrotating coordinate analysis, as well as by a more complex rotating coordinate analysis. Flight tests with a two-bladed rotor show that an in-plane hinged bar absorber can serve also as a gyro-stabilizer for the helicopter.

STRUCTURES

SOME ASPECTS OF DESIGNING ALUMINUM STRUCTURES FOR THERMAL ENVIRONMENTS. J. M. Cord and A. B. Burns. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-7. Members, $0.50; nonmembers, $1.00. 11 pp. Presentation of some general design aspects of extending the use of aluminum structure into the Mach 2.0 to Mach 3.0 region. A method is presented for determining the tensile yield and ultimate strength of aluminum alloys after exposure to a spectrum of elevated temperatures. This cumulative strength deterioration method uses the generally available strength versus exposure temperature time curves, and a simple logical relationship to account for multiple exposures. A brief test program devised to substantiate the method showed good correlation. The method has application in establishing new designs, in checking the effects of different thermal environments of an existing design, and as a time and cost saving approach to elevated temperature structural testing.

Cylinders & Shells

FLEXURE OF THIN-WALLED CIRCULAR CYLINDRICAL SHELLS. Appendix I - SOLUTION OF THE ELASTIC PROBLEM FOR A THIN-WALLED CIRCULAR CYLINDRICAL SHELL OF INFINITE LENGTH IN WHICH THE ONLY FORCE ACTING ON THE SHELL IS A UNIFORM PRESSURE ON ITS INNER SURFACE. Appendix II - RELATION OF W TO THE MEAN ANGLE OF ROTATION OF A CROSS-SECTION OF A THIN-WALLED CIRCULAR CYLINDRICAL SHELL. Appendix III - ERRORS ARISING FROM ACCURACY LIMITATIONS IN THE ELECTRONIC ANALOGUE COMPUTER WHEN SOLVING THE FLEXURAL EIGENVALUE PROBLEM FOR A UNIFORM "FREE-FREE" BEAM (SIMPLE BEAM THEORY). W. G. Hughes. Gt. Brit., RAE TN G.W. 525, Sept., 1959. 75 pp. Application of the approximations of membrane theory to develop equations which may be regarded as a direct extension of the equations of beam theory. The case of such a shell filled by a liquid mass is considered. Included is a comparison between shell and beam theory, as well as between a hydrodynamic and a simpler treatment of the liquid mass. The use of an analog computer is considered for the solution of eigenvalue problems associated with flexural vibrations of shell and beam structures.

TORSION AND EXTENSION OF HELICOIDAL SHELLS. J. K. Knowles and Eric Reissner. Quart. Appl. Math., Jan., 1960, pp. 409-422. ONR-supported analysis of the problem of rotationally symmetric deformations of thin elastic shells, the middle surface of which is a portion of a right helicoid. Particular consideration is given to the problem of a uniformly pretwisted thin strip which is acted upon by tractions which result in equal and opposite axial forces F, and equal and opposite axial torques T. The connection is established between rotationally symmetric states of strain which depend on states of displacement that are not rotationally symmetric. The relations between the applied force and torque on the one hand and the angle of elastic twist and the relative axial extension on the other hand are presented. These results generalize the earlier work of Chen Chu regarding the torsional rigidity of the strip.

RASCHET ORTOTROPNOI KONICHESKOI OBOLOCHKI NA PROIZVOL'NUIU VNESHNIUIU NAGRUZKU PO METODU V. Z. VLASOVA. V. A. Sibiriakov. MVO SSSR VUZ Izv. Av. Tekh., No. 2, 1959, pp. 72-82. In Russian. Derivation of equations for the calculation of conical shells subjected to an arbitrary external loading, such as would be encountered in the case of a nose cone. The general theory of Vlasov is used to determine the state of stress and deformation of the orthotropic conical shell. On the basis of physical hypotheses of this theory, related to the orthotropic semimomentless shells of medium length, only transverse bending moments are considered. The equilibrium equations are derived; the positive directions of forces and displacements are given; the method of successive approximations is used to derive the solution for the equation describing the state of elastic stress and deformation for the conical shell with deformed contour in the absence of shear deformation. An illustrative example is presented for various boundary conditions.

Fatigue

THE STATISTICAL BASIS OF LOADING SPECTRA FOR FATIGUE DESIGN CRITERIA. Innes Bouton. (USAF Fatigue Aircraft Struc. Symposium, Dayton, Aug. 13, 1959.) Aero/Space Engrg., Mar., 1960, pp. 53-57, 64. 21 refs. Discussion of the requirements for synthesizing loading spectra for new systems and the problems involved in calculating such spectra. It is concluded that there is still a need for a large-scale program to gather statistical data for loading spectra and for devising methods to utilize the statistical data in the design criteria. Statistical data on the eight parameters established for the present eight-channel data recording program form the minimum basis for rational fatigue criteria. The loading spectra usually must establish two functions. First, the past history of an aircraft at any time in its life must be determinable statistically in order to de-

termine the probable strength level (fatigue damage) of the structural elements at all times during the lifetime of the aircraft. Second, the probability of encountering a given magnitude load at any given time in the history of the component must be known in order to compute the probability at any given time. The aircraft probability of failure and its inverse, structural reliability, are the sum total of all the probabilities of failure during the previous history of the aircraft.

RAPID CRACK GROWTH IN SHEET STRUCTURE. E. J. Zapel. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-11. Members, $0.50; nonmembers, $1.00. 13 pp. Discussion of the general problem of crack propagation and presentation of an outline on the development of the strain energy release rate equations. A nomograph simplifying strain energy failure calculations is presented. Predicted gross area failure stress versus crack length curves are plotted for the family of E dW/dA values common to structural materials. A tabulation of E dW/dA values for several materials is given. The influence of stringer frame design upon the energy release rate is discussed in general terms, and an experimental means of determining this influence is proposed.

Plates with Holes

STRESSES AROUND REINFORCED ELLIPTICAL HOLES, WITH APPLICATIONS TO PRESSURE CABIN WINDOWS. W. H. Wittrick. Aero. Quart., Nov., 1959, pp. 373-400. Analysis using complex variable methods of the stress distribution due to an elliptical hole, reinforced around its boundary, in a plane sheet subjected at infinity either to an arbitrary constant stress system or to a bending type stress system. Numerical results were obtained for a wide range of parameters, including three different shapes of ellipse and ten different amounts of reinforcement. These results are used to investigate the stress concentrations which arise at elliptical pressure cabin windows and are due to the pressurization stresses. It is shown that, for each shape of ellipse, there is a limit to the reduction in stress concentration factor which can be achieved by increasing the weight of reinforcement; beyond this the stress concentration factor rises again.

Thermal Stress

THE INTRODUCTION OF CREEP INTO STRUCTURAL ANALYSIS. Carlo Riparbelli. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-9. Members, $0.50; nonmembers, $1.00. 19 pp. 17 refs. USAF-supported presentation of a numerical method for considering the effects of creep in the stress analysis of a redundant structure. The range of plastic strain to be considered is discussed and defined. A representation of the creep law in the form of a modified viscosity equation is proposed; it is subject to revision depending on the results of tests in progress. The creep rates to be introduced for biaxial stress distributions are computed from data available from uniaxial tests according to the von Mises-Prager condition. Calibration tests from substructures are preferred to obtain directly the creep rates to be introduced in the numerical analysis.

THERMAL STRESSES IN MISSILE NOSE CONES. Appendix I - SUMMARY OF ASSUMPTIONS LEADING TO THE UNCOUPLING OF THE TEMPERATURE AND STRESS DISTRIBUTION PROBLEMS. Appendix II - EXTENSION TO TEMPERATURE-DEPENDENT MATERIAL PROPERTIES. A. J. A. Morgan and C. H. Christensen. (IAS 28th Annual Meeting, New York, Jan. 25-27, 1960.) IAS, SMF Fund Paper No. FF-24, 1960. Members, $1.00; nonmembers, $2.00. 56 pp. 22 refs. Army-sponsored development of a general computational scheme for the determination of thermal displacements and stresses within multi-material bodies of axial symmetry. It is assumed that there has been previously given a set of temperature-distribution measurements and/or calculations. The method is applicable to "arbitrary" axially symmetric (solid or hollow) bodies, for which it may be necessary to use a discontinuous metric tensor to describe their geometry in two adjoining regions, under arbitrarily assigned time-dependent thermal, constraint, or loading boundary conditions. The numerical results of the theory are exact within the limits of linear thermoelasticity theory for generalized Duhamel-Neumann materials.

THERMODYNAMICS

THERMODYNAMIC PROPERTIES OF AIR IN THE TEMPERATURE INTERVAL FROM 1000 TO 12,000 K AND THE PRESSURE INTERVALS FROM 0.001 TO 1000 atm. E. V. Stupochenko, I. P. Stakhanov, E. V. Samuilov, A. S. Pleshanov, and I. B. Rozhdestvenskii. ARS J. Suppl., Jan., 1960, pp. 98-112. 19 refs. Translation. Investigation covering methods to calculate the statistical sums for atoms, molecules, and their ions; spectroscopic constants used in the calculation of statistical sums; effect of ionization, Coulomb interaction, and degeneracy of electron gas on values of thermodynamic functions; formulas for calculating the enthalpy, specific heat, and equilibrium constants in the temperature interval from 1,000° to 12,000° K.; solution of equations of chemical equilibrium of ideal gas systems; and thermodynamic analysis of reacting ideal gas systems in equilibrium state.

TRANSPORT PROPERTIES OF HIGH-TEMPERATURE MULTICOMPONENT GAS MIXTURES. E. A. Mason, J. T. Vanderslice, and J. M. Yos. Phys. Fluids, Nov.-Dec., 1959, pp. 688-694. 23 refs. USAF-supported investigation of some modifications in the kinetic theory of gaseous transport properties which are necessary to take account of effects encountered at high temperatures. It is shown that the results of classical kinetic theory can be kept in the same form, but the cross sections or collision integrals have to be computed differently. It is pointed out that the present modifications are valid to all orders of Chapman-Enskog

approximation. It is also shown that excitation exchange is important in determining the transport properties of mixtures at high temperatures, and the method of calculation of the excitation exchange probability is extended to cases for which multiple interaction curves are involved.

Combustion

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VTOL & STOL

THE AERODYNAMIC APPRAISAL OF STOL/VTOL CONFIGURATIONS. R. J. Vidal, A. Sowyrda, and R. A. Hartunian. IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-37. Members, $0.50; nonmembers, $1.00. 78 pp. 49 refs. Army-sponsored study of methods for estimating the characteristics of different STOL/VTOL configurations, emphasizing the effects of interactions between the lifting system and the propulsion wake. Certain aspects of the deflected slipstream configuration have been treated, and it is concluded that the classical model of a tubular propulsive jet cannot be physically realized. The velocity gradients due to the wing alter the solenoidal vortices defining the jet to form secondary or trailing vortices on the jet boundary. The effect of vertical gradients of velocity present in a propeller slipstream is discussed, and the theoretical and experimental results for the two-dimensional case show that there is an interaction effect associated with the slipstream velocity gradients and the wing thickness and camber which results in increased lift.

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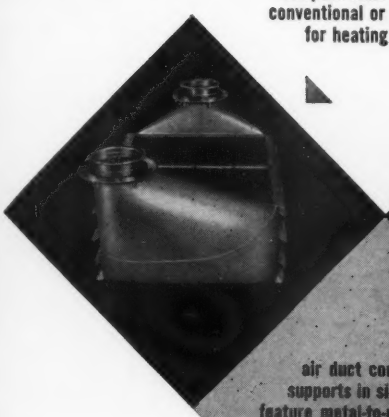

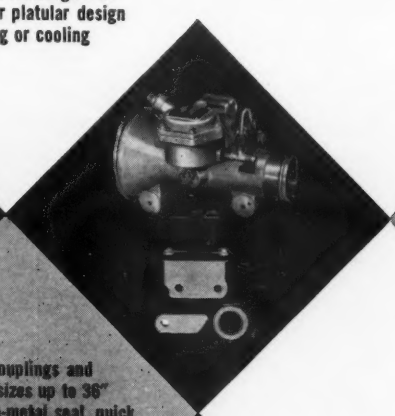

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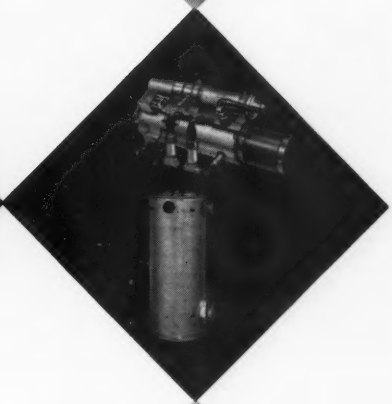

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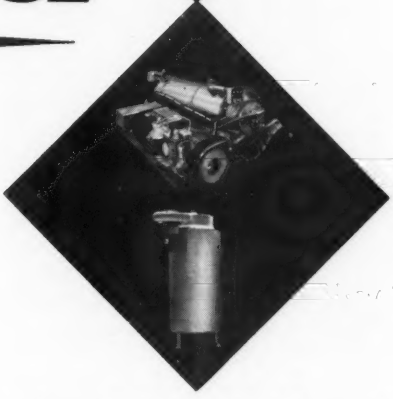

reliable components for missiles / aircraft / support

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Cylinders & Shells

On the Accuracy of Some Shell Solutions. G. D. Galletly and J. R. M. Radok. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59-APM-30.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 577–583. 11 refs. Outline of the method developed by Dingle for obtaining asymptotic solutions of ordinary differential equations of the type encountered in the bending theory for shells of revolution; comparative evaluation of the Langer method; and comparison of edge influence coefficients due to bending loads, obtained by using the asymptotic solutions and numerical integration of the equilibrium equations, respectively.

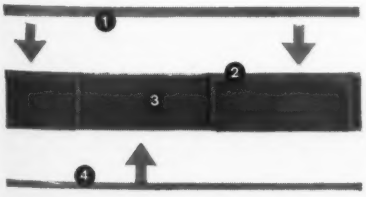
The Effect of End Conditions on the Dynamic Loading of Plastic Shells. P. G. Hodge, Jr. *J. Mech. & Phys. Solids*, Oct., 1959, pp. 258–263. Analysis considering a circular cylindrical shell of a rigid-plastic material uniformly loaded by a radial step pressure pulse. Explicit formulas are obtained for the maximum deformation in the shell as a function of the shell geometry and pressure magnitude. It is found that for moderately long shells the deformation is essentially independent of the support conditions at the end of the shell.

Johns-Manville Announces... MIN-KLAD INTERLOK

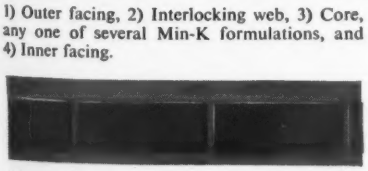
. . . a new structural system interlocking Min-K insulation and high-temperature reinforced plastic

Missile experience shows that in certain heat control situations no one material will perform as well as two (or more)—*an insulation with protective high-temperature facings.*

Problem is how to effectively combine these materials into a structurally strong unit? The answer is Min-Klad Interlok



1) Outer facing, 2) Interlocking web, 3) Core, any one of several Min-K formulations, and 4) Inner facing.



All the above components combine to provide a custom-made structural strong insulating system.

—a new structural system that interlocks Min-K insulation and reinforced plastic, metal or other high-temperature facings.

The result: one product that gives the missile designer every advantage of high-temperature plastic or metal foil—strength, toughness, rigidity! Erosion resistance! High heat capacity!

. . . plus the outstanding advantages of Min-K insulation—an insulating core that has the lowest thermal conductivity available for service temperatures up to 2000°F steady-state, and higher for transients. Min-K's thermal conductivity is actually lower than the molecular conductivity of still air.

Wide range of facings

For the hot face, the missile designer can specify Min-Klad Interlok in a wide variety of heat-resistant and/or ablating materials—asbestos-phenolic (ARP-40), and similar reinforced plastics, as well as stainless steel and other heat-resistant metal foils and meshes. For some requirements, the cool face can be made of a different material—for example, one that offers characteristics required for bonding or fastening to other surfaces and parts.

Like all J-M Aviation insulations, Min-Klad Interlok is factory-fabricated to your specifications into external skin panels, heat shields, cylindrical liners or component housings of any shape or size. Write today for technical specifications. Address Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS

Carrying Capacity of Elastic-Plastic Shells with Various End Conditions, Under Hydrostatic Compression. Burton Paul. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59–APM–16.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 553–560. ONR-sponsored research.

A Hinged Thin Shallow Spherical Shell Rectangular in the Horizontal Projection. B. Lawruk. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 413–418. Study of a thin shallow shell hinged on rigid diaphragms and subjected to a normal, functionally distributed load acting on its surface.

Bending and Stretching of Corrugated Diaphragms. R. F. Dressler. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958, Paper 58–A–62.*) *ASME Trans., Ser. D - BE*, Dec., 1959, pp. 651–659. USAF-supported solution of the exact linear elastic-shell equations for all stresses and displacements in a typical corrugated-diaphragm for three thicknesses varying over a nine to one range.

Elasticity & Plasticity

On the Foundations of the Theory of Elasticity of Plane Incompressible Non-Homogeneous Bodies. Józef Golecki. *Arch. Mech. Stosowanej*, No. 4, 1959, pp. 383–398. Analysis considering a two-dimensional elastic incompressible non-homogeneous body subject to plane strain.

A Non-Homogeneous Orthotropic Circular Segment as an Elastic-Plastic Problem. W. Olszak and S. Zahorski. *Arch. Mech. Stosowanej*, No. 4, 1959, pp. 409–419. 13 refs. Generalization of a problem solved by Shaffer and House with certain assumptions concerning the loading and deformation conditions, as well as the type of orthotropy and nonhomogeneity. A wide curved bar in the form of a circular segment is considered, subject to pure bending by two moments increasing monotonically and in a continuous manner with time *t*.

The Effects of Inelastic Action on the Resistance to Various Types of Loads of Ductile Members Made from Various Classes of Metals. XI—Photoelastic Analysis of I-Beams with Elliptic-Type Web Cutouts. W. J. Worley. *USAF WADC TR 56-330, Pt. XI*, Sept., 1959. 20 pp. Presentation of information on elastic stress distribution around the cutouts and comparison with available data on aluminum alloy I-beams.

Unloading Wave for a Body with Rigid Unloading Characteristic. Sylwester Kaliski and Jan Osiecki. *Vibration Prob. Proc.*, No. 1, 1959, pp. 49–66. Derivation of an exact closed solution for a semi-infinite bar, and presentation of a method for solving the cases with two particular examples of a sudden and an increasing-decreasing load.

A Problem on Stress Waves in an Infinite Elastic Plate. Appendix—**Stress Waves in an Infinite Isotropic, Elastic Plate Subjected to a Transverse Impulsive Line Load.** K. B. Broberg. *KTH Trans. 139*, 1959. 26 pp. Analysis considering an infinite, isotropic, elastic plate subjected to a transverse impulsive load at one point of its upper surface. The displacement at that point on the lower surface that is opposite to the point of impact has been calculated and evaluated numerically. Solution is found by using a method to due to Cagniard.

Impact and Moving Loads on a Slightly Curved Elastic Half Space. A. C. Eringen and J. C. Samuels. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59–A–2.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 491–498. ONR-sponsored application of two-dimensional Fourier transforms to the dynamic problem of an elastic half-space, considering such boundary curves as squares and triangular bumps and holes, as well as sinusoidal and periodic boundaries. Various types of surface loadings are studied, and closed-form results are given for a uniform pulsating pressure load.

On Plane-Stress Solution of a Compressible Wedge with the Use of Mises' Yield Condition. A. Kalnins. *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 676–678. Navy-sponsored research.

Fatigue

Fatigue Loadings in Flight: Loads in the Tailplane and Fin of a Jet Provost. Appendix I—**Flight Tests.** Appendix II—**Estimation of Load Occurrences in a 120 Hour Training Course.** Anne Burns. *Gt. Brit., ARC CP 440*, 1959. 36 pp. BIS, New York, $0.81. Presentation of data on the fluctuating and steady loads measured during flight of a Jet Provost. Conditions include take-off, landing, taxiing, flight in turbulence, aerobatics, and the use of the air-brakes and flaps.

Plates

Bending of Thin Rectangular Plates with Edge Beams. M. N. Keshava Rao. *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 686–688. Presentation of equations leading to the solution of the general problem of a plate with edge beams having different flexural and torsional rigidities.

Flexure of Nonhomogeneous Cylindrically Aeolotropic Plate. R. L. Thorkildsen and W. H. Hoppmann, II. *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 669–672. Presentation of a method for determining the deflection of a circular plate in which the elastic constants are cylindrically aeolotropic but vary along the radius.

Transient Analysis of Stress-Wave Penetration in Plates. Norman Davids. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59–A–16.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 651–660. 15 refs. Army-sponsored study of the propagation of a transient stress pulse concentrated at a point on the boundary of a plate whose thickness is of the order of a wavelength.

Stan Naprezenia i Przemieszczenia w Grubej Plycie Kotowej Wywotany Dziataniem Nieustalonego Pola Temperatury. Włodzimierz Derski. *Rozprawy Inżynierskie*, No. 2, 1959, pp. 191–233. 10 refs. In Polish, with summaries in English and Russian. Analysis of the stress and displacement in a thick circular plate due to a nonsteady axially symmetric temperature field.

General Expressions for the Boundary Conditions and the Differential Equation of Equilibrium and Vibration of an Anisotropic, Non-Homogeneous Plate. Z. Mazurkiewicz. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No 9, 1959, pp. 519–530.

Strength of an Unlimited Disc with a Rigid Medium. H. Czudek. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 425–430. Study of the problem of one-directional tension in an unlimited disc with a rigid medium of a circular elliptical, triangular, or square shape, or that of a straight slit. The analysis is used to determine the state of stress in the disc due to sections welded onto the disc, as well as the welding stresses, provided the welded elements are sufficiently rigid.

Dynamic Plastic Deformations of Simply-Supported Square Plates. A. D. Cox and L. W. Morland. *J. Mech. & Phys. Solids*, Oct., 1959, pp. 229–241. 10 refs. Analysis of a simply supported plate subjected to a uniformly distributed rectangular pressure pulse. All effects due to elastic strain, work hardening, and strain rate are neglected and, to simplify further, Joansen's yield criterion is adapted as an approximation to that of Tresca.

A Semi-Infinite Plate Under the Action of Internal Load. F. Szelągowski. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 431–436. Analysis of the state of stress in a plate representing a half-plane, due to the action of concentrated internal forces and moments.

Plates with Holes

Transverse Flexure of a Semi-Infinite Thin Plate Containing an Infinite Row of Circular Holes. O. Tamate. (*ASME West Coast Conf., Stanford, Sept. 9–11, 1959, Paper 59–APMW–15.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 661–665. 10 refs.

Sandwich Construction

Sandwich Structure for High Temperature Vehicles. H. R. Ashley. (*NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 216*, Oct., 1958. 38 pp. Review of data on high-temperature sandwich structure from the viewpoint of theoretical structural efficiency and practical design and manufacturing.

Testing Methods

Development of a Fatigue Testing Apparatus for Testing Honeycomb Sandwich Structural Panels in Service-Simulated Sonic Fatigue. E. F. E. Zeijdel and W. H. Ashley. *USAF WADC TR 59-231*, Sept., 1959. 33 pp. Description of theoretical and experimental investigations indicating the need of a 200,000 volts a.c. generator to simulate electrostatic fields. Due to the expense of the project an alternative method is discussed. In addition, it is indicated that the medium surrounding the test specimen must be changed to prevent corona discharge.

Equipment for "Watching" Propagation Stress Waves. H. Becker. *Rev. Sci. Instr.*, Dec., 1959, pp. 1107–1109. Description of an experimental arrangement in which the propagation of stress waves generated by impact may be "watched" photoelastically. In addition to providing control over the observed progress of the wave, the apparatus makes possible photography of the wave with conventional cameras.

A Photoelastic Approach to Transient Stress Problems Employing Low-Modulus Materials. J. W. Dally, W. F. Riley, and A. J. Durelli. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59–A–10.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 613–620. 16 refs. USAF-sponsored research.

High-Temperature Testing of Aircraft Structures. R. R. Heldenfels. (*NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 205*, Oct., 1958. 38 pp. 32 refs. Discussion of equipment and techniques used for high-temperature testing of aircraft structures and materials at NASA Langley Aeronautica Laboratory.

Thermal Stress

On Inertia Effects in a Transient Thermoelastic Problem. Eli Sternberg and J. G. Chakravorty. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59–APM–9.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 503–509. 14 refs. ONR-supported study of the transient thermoelastic problem for a semi-infinite medium which is constrained against transverse displacements and is exposed to a uniform time-dependent heating (or cooling) of its entire plane boundary. The displacements are determined in closed form, the field of thermal stress is compared with the corresponding quasi-static stress distribution, and the results are compared with data from earlier investigations.

The Dynamic Stresses Produced in Elastic Bodies by Uneven Heating. G. Eason and I. N. Sneddon. *Royal Soc. (Edinburgh) Proc., Sect. A*, 1958-1959, Pt. II, pp. 143–176. 20 refs. Derivation of general solutions of the equations of thermoelasticity in two simple situations: (a) when the stresses are produced in an infinite solid by a given distribution of heat sources, and (b) when the stresses are produced in a semi-infinite solid by imposing a prescribed distribution of temperature on the plane boundary of the solid.

General Introduction to Thermal Structures. James Taylor. (*NATO AGARD 8th Structures & Materials Panel Meeting, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 206*, Oct., 1958. 20 pp. 13 refs. Survey of the basic data on aerodynamics and materials, including review of the developed structural theory. Procedures for using these in selecting structural shapes for particular application are suggested. Also included is a discussion on the technique combining strains due to temperature and those due to load.

Large Deflections of Structures Subjected to Heating and External Loads. M. J. Turner, E. H. Dill, H. C. Martin, and R. J. Melosh. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Rep. 59-26.*) *J. Aero/Space Sci.*, Feb., 1960, pp. 97–106, 127.

Mechanism and Mechanics of Creep of Plastics. I. W. N. Findley. *SPE J.*, Jan., 1960, pp. 57–65. 17 refs. Study of the mechanism of creep considering three classes of plastics: (a) linear polymers, (b) space polymers, and (c) reinforced plastics. Mechanical models of creep under varying stress are described along with such concepts as the mechanical equation of state, strain and time hardening, and the principle of superposition.

Thermal Stress Propagation in Visco-Elastic Bodies. II. W. Nowacki. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, pp. 459–467. Extension of previous work to the case of thermal stress due to a linear or plane source of heat.

A General Approach to the Practical Solution of Creep Problems. A. Mendelson, M. H. Hirschberg, and S. S. Manson. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958, Paper 58–A–98.*) *ASME Trans., Ser. D - BE*, Dec., 1959, pp. 585–594; Discussion, pp. 595–598. 10 refs. Presentation of a method applicable to different creep laws and loading paths. Examples are presented for the creep in a flat plate with a temperature gradient and for several cases of rotating discs.

Thermal Stresses Owing to a Hot Spot in a Rectangular Strip. C. W. Nelson. (*ASME Annual Meeting, Atlantic City, Nov. 29–Dec. 4, 1959, Paper 59–A–8.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 488–490. Application of the Fourier integral approach to derive the thermal stresses for the plane-stress problem of a circular hot spot in an infinitely long straight strip of rectangular cross section. Numerical values are given for the stresses on the edges and both centerlines of the strip for a particular case.

The Propagation of Thermal Stresses in Thin Metallic Rods. I. N. Sneddon. *Royal Soc. (Edinburgh) Proc., Sect. A*, 1958-1959, Pt. II, pp. 121–142. 14 refs. Calculation of the distribution of temperature and stress in an elastic rod when its ends are subjected to mechanical or thermal disturbances. Simple waves in an infinite rod are first discussed, followed by boundary value problems for semi-infinite rods and rods of finite length. An approximate method of solving the equations of thermoelasticity is also presented.

A Certain Dynamic Problem of Thermoelasticity Concerning the Circular Disc. W. Piechocki. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, No. 9, 1959, pp. 513–518. Analysis of the state of displacement and stress in a circular disc due to the action of a heat source varying harmonically in time. Isotropy and homogeneity are assumed both for thermal and elastic properties.

Note on a Thermoelastic Problem for a Transversely Isotropic Hollow Sphere Embedded in an Elastic Medium. J. Nowinski. (*ASME Summer Conf., Troy, June 18–20, 1959, Paper 59–APM–27.*) *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 649, 650. USAF-supported research.

Thermal Stresses due to a Thermal Inclusion in a Circular Ring and a Spherical Shell. W. Piechocki and J. Ignaczak. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 419–424. Determination of the state of stress in a circular ring and a spherical shell due to a discontinuous temperature field. In both cases the solution is represented in the form of a series, the coefficients of which constitute the solution of a system of algebraic equations with four unknowns.

A Plane Dynamic Problem of Thermoelasticity Concerning a Circular Hole. *Acad. Pol. Sci. Bul., Tech. Sci. Ser.*, Nos. 7-8, 1959, pp. 469–475. Analysis of a problem of stress-wave propagation due to a line source parallel to the axis of the infinite cylinder. It is assumed that the temperature and the stress of the lateral surface of the cylinder are zero.

Dynamic Thermoelastic Problem of a Spherical Cavity. Józef Ignaczak. *Arc. Mech. Stosowanej*, No. 4, 1959, pp. 399–408. Analysis considering the propagation of elastic waves in the vicinity of a spherical cavity, due to the action of a concentrated heat source varying with time.

Wings

Structural Analysis of High Speed Wings for a Quasi-Triaxial Elastic State in the Skin, Bi-Axial in the Longitudinals. P. J. Theodorides. *U. Md. Inst. Fluid Dynamics & Appl. Math. Paper*, 1957, pp. 71–85. 26 refs. Reprint. USAF-sponsored presentation of a method of structural analysis based on an improved plate theory. Elastic interplay of skin and stiffness is considered, attempting to avoid the intricacies of thick skin theory and defects in Kirchhoff's method.

Thermodynamics

The Minimum-Weight Straight Fin of Triangular Profile Radiating to Space. E. N. Nilson and Richard Curry. *J. Aero/Space Sci.*, Feb., 1960, pp. 146, 147.

Minimizing the Mass of Thin Radiating Fins. J. E. Wilkins, Jr. *J. Aero/Space Sci.*, Feb., 1960, pp. 145, 146. Derivation of a method for mass reduction in fins by taking advantage of the freedom to choose the fin profile.

Combustion

The Burning Velocity of Hydrogen-Air Mixtures and Mixtures of Some Hydrocarbons with Air. T. G. Scholte and P. B. Vaags. *Comb. & Flame*, Dec., 1959, pp. 494–501. Description of an apparatus for measuring the burning velocity of gas-air mixtures within an accuracy of about 5 per cent. Data are presented for various gas-air mixtures.

The Influence of Small Quantities of Hydrogen and Hydrogen Compounds on the Burning Velocity of Carbon Monoxide–Air Flames. T. G. Scholte and P. B. Vaags. *Comb. & Flame*, Dec., 1959, pp. 503–510. 14 refs.

Burning Velocities of Mixtures of Hydrogen, Carbon Monoxide and Methane with Air. T. G. Scholte and P. B. Vaags. *Comb. & Flame*, Dec., 1959, pp. 511–524.

Notes on Gaseous Nitric Acid–Hydrocarbon Flames. J. Mertens and R. L. Potter. *Comb. & Flame*, Dec., 1959, pp. 525–527. Study showing that substitution of argon for nitrogen as shielding fluid about nitric acid hydrocarbon flames does not change the spectra involving CN and NH radicals. In addition, photographs in color show qualitative difference between low- and high-temperature inlet gases.

Structure of Hydrocarbon (C_2)-Oxygen Flames. R. M. Fristrom, W. H. Avery, and C. Grunfelder. (*Quart. Rev. Bumblebee Activ.*, Jan.-Dec., 1958.) *Johns Hopkins U. APL BB Rep. 283*, 1959, pp. 29–34. Survey of the chemistry of three lean hydrocarbon (C_2)-oxygen flames. The precision of the flame sampling method permits quantitative interpretation of the concentration profiles. Conditions for these flames were chosen so as to minimize chemical complications and to match physical properties.

Mechanism of Propane-Air Reaction Based on Analysis of Flame Front Profiles. R. M. Fristrom, A. A. Westenberg, and W. H. Avery. (*Quart. Rev. Bumblebee Activ.*, Jan.-Dec., 1958.) *Johns Hopkins U. APL BB Rep. 283*, 1959, pp. 1–4. Discussion of techniques for studying the structure of flame fronts as the new source of information on high-speed, high-temperature reactions. Application is made to a propane-air flame to establish the existence of a single dominant reaction for the initial attack of propane.

Blowoff of Propane and Hydrogen Diffusion Flames at High Mach Number, Ramjet Conditions. R. J. Bacigalupi and E. A. Lezberg. *U.S., NASA TN D-67*, Dec., 1959. 24 pp. Presentation of blow-off conditions for flames stabilized in the wake of cylindrical fuel injectors. The effect of varying pressure, temperature, and air and fuel flows is determined for several fuel-orifice and tube diameters. The propane blow-off and hydrogen data are correlated; the correlations are derived from a thermal ignition model for flame stabilization.

Considerations Pertaining to Spherical-Vessel Combustion. J. Grumer, E. B. Cook, and T. A. Kubala. *Comb. & Flame*, Dec., 1959, pp. 437–446. 12 refs. ONR-sponsored discussion on the interpretation of measured flame speed and pressure rise rates during combustion in a spherical vessel. This deals with recent improvements in theory and verification of the previous findings that the pressure exponent of the burning velocity is positive for some mixtures. The ability to measure approximately expansion ratios of gases burning in a closed vessel and new tests for thermochemical equilibrium in the burnt gases are also reported.

Further Measurements of Turbulence Intensity in Flame Zones. A. A. Westenberg and J. L. Rice. *Comb. & Flame*, Dec., 1959, pp. 459–465. Navy-supported extension of a system reported previously to study the interaction of flame and turbulence at positions throughout a duct.

Quenching Diameters of Some Fast Flames at Low Pressures. E. Anagnostou and A. E. Potter, Jr. *Comb. & Flame*, Dec., 1959, pp. 453–457. 12 refs. Presentation of quenching diameters as a function of pressure for some fast stoichiometric hydrocarbon-oxygen and hydrogen-oxygen flames. The order of increasing ease of quenching is acetylene, ethylene, hydrogen, and propane.

Method for the Study of Deflagration to Detonation Transition. F. C. Gibson, M. L. Bowser, and Ch. M. Mason. *Rev. Sci. Instr.*, Oct., 1959, pp. 916–919. Development of a method, based on the variation of electrical resistance in a wire element introduced into the charge, for the continuous measurement of burning and detonation rates in opaque materials.

Heat Transfer

Experimental Studies of Free Convection Heat Transfer. Tetsu Fujii. *JSME Bul.*, Nov., 1959, pp. 555–558. Description of experiments showing that local heat transfer coefficients, which are measured directly, are scarcely affected by the development of the vortex street in the boundary layer, but discontinuously increased by the transition to a turbulent flow.

An Analysis of Turbulent Free Convection Heat Transfer from a Vertical Surface. Tetsu Fujii. *JSME Bul.*. Nov., 1959, pp. 559–563. 10 refs. Presentation of approximate solutions for the transient turbulent boundary layer and the fully turbulent boundary layer.

Periodic Temperature Distribution in Laminated Solids. R. J. Grosh. *USAF WADC TN 59-185*, July, 1959. 20 pp. 37 refs. Analysis of periodic heat conduction in plane, cylindrical, and spherically laminated solids. Attention is given to cases of isotropic laminates, with constant product of density and specific heat and space varying thermal conductivity, after the transient period state has disappeared.

Free Convection Past a Vertical Flat Plate: Some Numerical Results. J. B. Baron and Morton Finston. *MIT NSL TR 269*, Mar., 1959. 23 pp. Presentation of exact solutions in numerical form for the free convection flow past a vertical plane surface of nonuniform temperature.

Heat Transfer from a Nonisothermal Disk Rotating in Still Air. J. P. Hartnett. *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 672, 673. 10 refs.

A Solution of the Steady Linear Heat-Flow Equation with Heat Generation and Conductivity Arbitrary Functions of Temperature. R. P. Stein. *ASME Trans., Ser. E - AM*, Dec., 1959, pp. 685, 686.

Two Heat Diffusion Problems with Shock Tube Applications. D. A. Spence. *Gt. Brit., RAE TN Aero. 2637*, July, 1959. 16 pp. Presentation of a method for estimating the error introduced by edge effects in the calibration by Joule heating of thin film resistance thermometers for use in shock tubes. The second problem dealt with is the variation of the surface temperature at the stagnation point of a bluff body in a shock tube.

Publications abstracted may be borrowed from the IAS Library. In making inquiry, please mention the month of *Aero/Space Engineering* in which the abstract appeared. This will facilitate servicing of requests.

VTOL & STOL

Ryan Versatile Vertifan. *Ryan Reporter*, Oct. 14, 1959, pp. 18, 19, 25. Discussion of a system featuring a fan or a set of fans, horizontally submerged within the wing and powered by a tip turbine, driven by the jet engine exhaust to provide the lift for vertical take-off and hovering.

An Investigation to Determine Conditions Under Which Downwash from VTOL Aircraft Will Start Surface Erosion from Various Types of Terrain. R. E. Kuhn. *U.S., NASA TN D-56*, Sept., 1959. 43 pp. 11 refs.

Ducted Propellers—A Critical Review of the State of the Art. A. H. Sacks and J. A. Burnell. *Hiller Aircraft Adv. Res. Div. Rep. ARD-232*, June 26, 1959. 71 pp. 125 refs.

Preliminary Study of the Hovering Performance of Annular Jet Vehicles in Proximity to the Ground. Appendix A—Derivation of Approximate Power Relations. Appendix B—Procedure Employed in Estimating Weights. Harvey Chaplin and Bertrand Stephenson. *U.S., Navy Dept., David Taylor Model Basin Rep. 1374; Aero Rep. 947 (TED TMB AD-3242)*, Aug., 1958. 25 pp. Derivation of an approximate theoretical method of estimating power required for an annular jet vehicle with near-optimum nozzle geometry. Charts showing the approximate relations between size, altitude, gross weight, and power are developed by this method.

Wind-Tunnel and Piloted Flight Simulator Investigation of a Deflected-Slipstream VTOL Airplane, the Ryan VZ-3RY. H. A. James, R. C. Wingrove, C. A. Holzhauser, and F. J. Drinkwater, III. *U.S., NASA TN D-89*, Nov., 1959. 88 pp. 14 refs. Study of the characteristics of a deflated-slipstream VTOL aircraft during a transition from hovering to normal flight. The longitudinal, lateral, and directional stability and control characteristics of the vehicle are measured in the tunnel.

Full-Scale Wind-Tunnel Investigation of the Longitudinal Characteristics of a Tilting-Rotor Convertiplane. D. G. Koenig, R. K. Greif, and M. W. Kelly. *U.S., NASA TN D-35*, Dec., 1959. 39 pp. Presentation of test results for the XV-3 convertiplane. Aircraft configuration variables were angle of attack, rotor-pylon angle, power, and longitudinal control. With the exceptions of a few tests made at or near zero airspeed, most of the tests were made at approximately 60 and 120 knots. Rotor characteristics, aircraft static stability, and several conversion procedures are analyzed.

An Analysis of Steady Straight Flight with Inclined Thrust. Appendix I—Method of Calculation of Performance Diagrams. Appendix II—Angular Relations When $\lambda > 1$. Appendix III—Variation of Performance with Thrust Inclination. S. B. Gates and A. W. Thorpe. *Gt. Brit., ARC R&M 3096* (Mar., 1953) 1959. 32 pp. BIS, New York, $2.07. Study of Griffith's proposal for jet aircraft in which the sea-level thrust must exceed the weight and should be continuously rotatable through 90° from its normal direction in order that the aircraft should take-off and land vertically in the usual attitude. A vectorial method of analysis is used in displaying the special features of the performance of such aircraft at both high and low speed.

Wind-Tunnel Investigation of Effect of Ratio of Wing Chord to Propeller Diameter with Addition of Slats on the Aerodynamic Characteristics of Tilt-Wing VTOL Configurations in the Transition Speed Range. R. T. Taylor. *U.S., NASA TN D-17*, Sept., 1959. 42 pp.

A Flight Study of the Conversion Maneuver of a Tilt-Wing VTOL Aircraft. L. P. Thomas, III. *U.S., NASA TN D-153*, Dec., 1959. 11 pp. Test results showing that the configuration is capable of performing continuous slow level-flight conversions with no major longitudinal trim changes. Studies have shown that the explanation of this ability lies in the shift with wing incidence of the curves of longitudinal stick trim position plotted against airspeed and the direction of the slopes of these curves at intermediate incidences.

Water-Based Aircraft

A Brief Investigation of the Effect of Waves on the Take-Off Resistance of a Seaplane. E. J. Mottard. *U.S., NASA TN D-165*, Dec., 1959. 17 pp.

The Full-Scale Air Drag of Some Flying-Boat Seaplanes. A. G. Smith. *Gt. Brit., ARC R&M 3082* (Feb., 1956) 1959. 56 pp. 24 refs. BIS, New York, $3.60. Presentation of data on the Sunderland, Solent, Shetland, Sealand, Saro E. 6/44, and Princess seaplanes.

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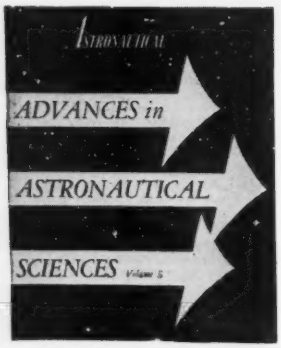

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This latest volume in the series is the proceedings of the Western National Meeting of the American Astronautical Society which was held in August, 1959. The volume includes the opening address by Dr. Wernher von Braun, and 26 reports which represent original technical research both from theoretical and experimental aspects. Topics under discussion include Space Mechanics, Control and Guidance; Advanced Propulsion and Power; Astronautical Systems and Space Vehicle Design; Space Communication and Instrumentation; Lunar and Planetary Environment. This detailed picture of the scope of current astronautical research will prove invaluable to the scientist, as well as form an excellent guide for the informed layman who desires an insight into the current problems of astronautics.

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The increasing contemporary importance of this scientific phenomenon was dramatically indicated by the unexpectedly large attendance at the 1959 Conference on Exploding Wires. This volume, a complete record of the conference, includes reports of theoretical research in the field and new developments and applications. In this book—the first ever published on the subject *in any language*—scientists, students, and technologists will find a wealth of incisive material dealing with high-speed photographic techniques, shock waves, and the physics of fluids.

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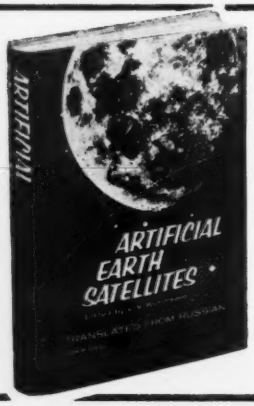

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Edited by L. V. Kurnosova **Translated from Russian**

The publication of this double-volume book marks the appearance of the first translation of the revised texts of the reports read at the Fifth Assembly of the Special IGY Committee, which took place at Moscow in August, 1958. Volume 1 explores data obtained by the first two satellites and includes discussions on the ionosphere, cosmic radiation, and space biology. (Data collected on *the first astronaut*—the dog Laika —are presented.) Volume 2 documents work carried out with the third satellite (which contained a complete space laboratory), as well as with rockets.

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These five volumes are the proceedings of the Cryogenic Engineering Conferences held in 1954, 1956-1959. (There was no meeting in 1955.) Subjects under discussion include: Cryogenic Tankage for Space Flight Applications; A Study of Condensing-Vacuum Insulation; Multiple-Layer Insulation; Nucleate- and Film-Boiling Studies with Liquid Hydrogen; The Liquefaction of Natural Gas; Some Mechanical Properties of Magnesium Alloys at Low Temperatures; An Experimental Study Concerning the Pressurization and Stratification of Liquid Hydrogen; Maximum-Rate Theory of Impact Sensitivity.

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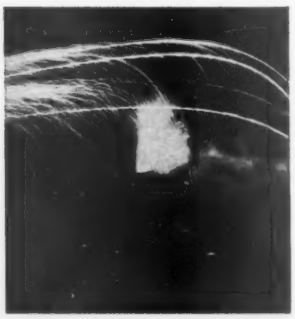

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REVIEWS OF *Books*

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AERODYNAMICS. FLUID MECHANICS

Turbulence; An Introduction to its Mechanism and Theory. J. O. Hinze. New York, McGraw-Hill Book Co., Inc., 1959. 586 pp., illus., diagrs. $15.

The text originates from a series of lectures given by the author to chemical engineers of the Royal/Dutch-Shell laboratories at Amsterdam and Delft during 1950. The material, which has been brought up to date, is designed to familiarize both chemical and mechanical engineers with the role played by turbulence in problems of mixing and heat and mass transfer, as well as the mechanism of turbulence in relation to flow resistance. Not all questions about turbulence are considered. For instance, instability theories and transition from laminar to turbulent flow is not mentioned, and the effect of compressibility of the fluid on turbulence phenomena has been touched upon only incidentally. Although the treatment starts from first principles and the use of mathematics has been reduced to a minimum, a fair knowledge of mathematics and physics is prerequisite to an adequate comprehension of the text.

Professor Hinze is Professor of Fluid Mechanics, Technological University, Delft.

Open-Channel Hydraulics. Ven Te Chow. New York, McGraw-Hill Book Co., Inc. 1959. 680 pp., illus., diagrs., tables. $17.

This textbook for both undergraduate and graduate students is also designed as a compendium for practicing engineers. The use of advanced mathematics is deliberately avoided as much as possible, and the explanation of hydraulic theories is greatly simplified as far as practicable.

The text is organized into five parts, the first three of which would ordinarily be treated in a one-semester course on open-channel hydraulics. *Part 1* is on basic principles. *Part 2* discusses uniform flow and *Part 3* gradually varied flow. In *Part 4*, on rapidly varied flow, the treatment of the problem is largely supported by experimental data because this type of flow is so complicated that a mere theoretical analysis in most cases will not yield sufficient information for the purpose of practical design. In *Part 5*, on unsteady flow, the treatment is general but practical; a higher level of advanced mathematics would be required for a comprehensive treatment. The subject matter dwells mainly on the flow of water in channels where water contains little foreign material, therefore river hydraulics, tidal hydraulics, and coastal engineering are beyond the scope of this book.

Dr. Chow is Professor of Hydraulic Engineering and currently heads the hydraulic engineering research and teaching programs at the University of Illinois.

CONTROL THEORY

Digital and Sampled-Data Control Systems. Julius T. Tou. New York, McGraw-Hill Book Co., Inc., 1959. 631 pp., diagrs., tables. $15.

The material presented is mainly the outgrowth of a set of lecture notes, first prepared in 1956, for a course offered by the author to graduate students at the Moore School, University of Pennsylvania. To the student, it presents in step-by-step fashion (the simpler to the more difficult) a discussion of basic theory and important techniques; for the practicing engineer, it provides in systematic form a ready source of reference material. As a background to the text, it is assumed that the reader has adequate preparation in an introductory course on feedback control systems and has a sound knowledge of Laplace transforms and complex variable theory.

In addition to many numerical examples worked out in the text, Dr. Tou, who is Associate Professor of Electrical Engineering, Purdue University, has included three appendixes which furnish the reader with tables of z transforms and modified z transforms, numerous references to pertinent literature, and approximately 70 problems of various types and complexity.

DICTIONARIES

Encyclopedic Dictionary of Electronics and Nuclear Engineering. Robert I. Sarbacher. Englewood Cliffs, N.J., Prentice-Hall, Inc., 1959. 1417 pp., illus., diagrs., tables. $35.

This massive new reference work is the fruit of 12 years of labor by Dr. Sarbacher, who designed it to be of use to a wide spectrum of scientific and industrial workers. There are approximately 14,000 entries (in alphabetic order) and 1,400 illustrations. Cross references are incorporated on an equally extensive scale, numbering more than 17,000. Under the word "antenna," for example, there are 206 entries and 92 illustrations.

Wherever practicable, definitions prepared and approved by the various professional societies have been used, and an abbreviation following any entry identifies the source of that entry as one of these organizations. Also included are authorized Armed Forces definitions and abbreviations (acronyms) of military establishments concerned with electronics and nuclear engineering. In addition, the dictionary contains a number of terms which, strictly, are not unique to electronic or nuclear terminologies; these include terms of elemental electric and magnetic theory and of atomic physics, as well as a number of definitions from the broader principles of physics.

Dr. Sarbacher currently serves as Professional Lecturer at George Washington University and heads the consulting firm of Robert I. Sarbacher and Associates.

Glossary of Meteorology. Edited by Ralph E. Huschke. Boston, American Meteorological Society, 1959. 638 pp., $12.

The *Glossary of Meteorology*, which aims to define every important meteorological term likely to be found in the literature today, consists of an alphabetical list of words and short phrases followed immediately by their definitions or by preferred synonyms. Occasionally the reader is referred to a related term whose definition contains an explanation of the term in question, and, where a term has more than one definition, each is numbered and the first definition is the most common or, meteorologically, the most important, or both.

The collecting of terms appearing in this glossary began in 1952 with an exhaustive survey of the literature of the preceding 5 years. This list, plus previous collections, provided the platform on which the final product was assembled and, with the deletion of many old terms and the addition of far newer ones, resulted in a final count of 7,247 entries, which are intended to provide adequate information with a minimum of time and effort required of its user.

EDUCATION AND TRAINING

Your Career as an Aerospace Engineer. Published under the Auspices of the Minta Martin Aeronautical Student Fund. New York, Institute of the Aeronautical Sciences, Inc., 1960. 24 pp., illus.

Aimed primarily at the high school student, this manual treats of the responsibilities and rewards of a career as a professional aerospace engineer. It contains an analysis of the activities of the aerospace industry, brief job descriptions, and discussion of the challenges that lie ahead, both for the industry and for the men who will work in it. The kind of man an engineer must be in the jet and space age is a featured topic.

There is a comprehensive section on how a high school student can prepare for his college years; this covers an estimate of tuition costs, the financial assistance available, and a typical aeronautical engineering curriculum. The merits of graduate school training are pointed out. Schools of engineering in the United States which have been accredited by the ECPD are listed.

ELECTRONICS

Electronic Components Handbook; Vol. 3. Transformers and Inductors, Connectors, Wire and Cable, Terminals, Tube Shields, Hardware. Edited by Keith Henney, Harry Mileaf, and Craig Walsh. Sponsored by Electronic Components Laboratory, WADC, USAF. New York, McGraw-Hill Book Co., Inc., 1959. 180 pp., illus., diagrs., tables. $10.

This is the third and final volume of a series of working manuals prepared for the designers of military electronic equipment and is intended to provide the engineer with essential data on component parts so that he may select and use those parts that perform with maximum reliability. Emphasis throughout this volume has been placed on component types for which military specifications are available, but other types are included in the discussions as well. Where such military specifications exist, they are summarized.

Modern Network Analysis. Fazlollah M. Reza and Samuel Seely. New York, McGraw-Hill Book Co., 1959. 373 pp., diagrs., tables. $10.

The authors have set as their goal a text that would provide the student with a broad understanding of modern network analysis at a modest level of sophistication. It does not seek to provide a high level of mathematical development for those who might have a professional interest in network theory.

The book is organized and divided into three parts. *Part 1* presents a systematic introduction to the study of network analysis, primarily under steady-state exponential excitation. *Part 2* discusses some of the classical applications of *Part 1* to filters and transmission lines, and *Part 3* presents a study of linear networks in the transient state and also a number of consequent general properties of such systems.

The authors are, respectively, Professor of Electrical Engineering, Syracuse University, and Head, Department of Electrical Engineering, Case Institute of Technology.

INSTRUMENTS

Instrumentation in Scientific Research; Electrical Input Transducers. Kurt S. Lion. New York, McGraw-Hill Book Co., Inc., 1959. 324 pp., illus., diagrs., tables. $9.50.

The purpose of this volume is to offer research workers, engineers, and students a reasonably complete collection of the existing basic methods and systems used as input transducers in electrical instrumentation; to serve as a reference book which will minimize literature search; and to provide information on particular methods, as well as criteria by which the relative merits of existing methods and systems may be evaluated. The level of presentation is chosen for those who have a moderate knowledge of physics and mathematics. The physics of each method has been given preference over the technical means. Mathematical derivations are omitted; where the derivation is not obvious, it may be found in the references.

The author is an Associate Professor, Massachusetts Institute of Technology.

MATERIALS

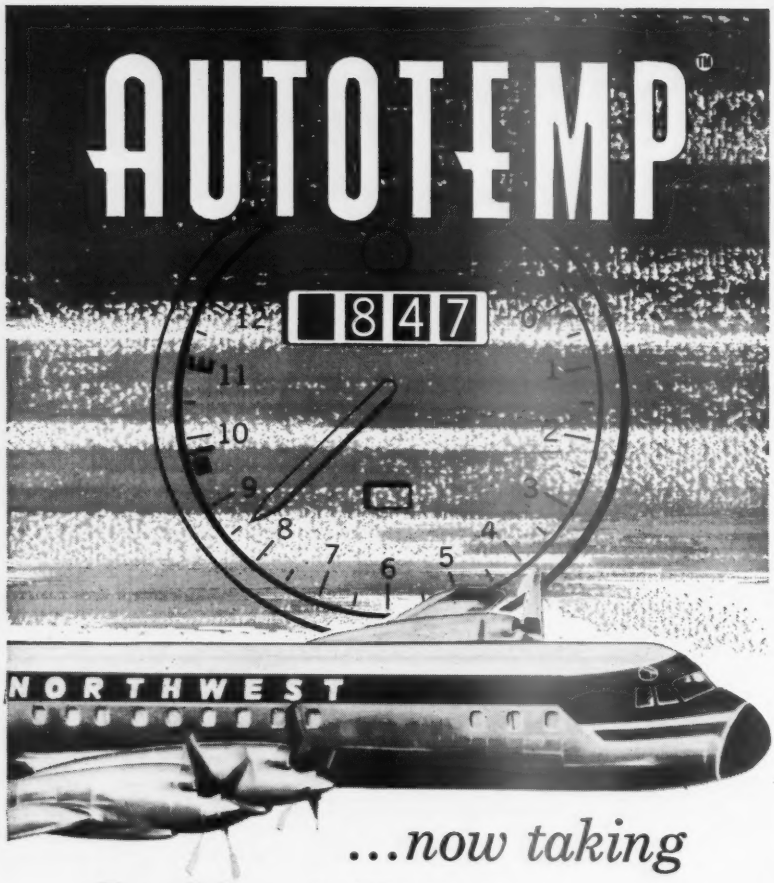
Introduction to Rubber Technology. Edited by Maurice Morton. New York, Reinhold Publishing Corp., 1959. 547 pp., illus., diagrs., tables. $10.

Contents: (1) History and Summary of Rubber Technology, B. S. Garvey, Jr. (2) Introduction to Polymer Chemistry, M. Morton. (3) Natural Rubber, O. D. Cole. (4) Vulcanization, L. E. Oneacre. (5) Accelerators of Vulcanization, B. S. Garvey, Jr. (6) Antioxidants and Antiozonants, R. R. Barnhart and T. H. Newby. (7) Rubber Plasticizers, Softeners, and Extenders, F. M. McMillan. (8) Carbon Black, J. W. Snyder and M. H. Leonard. (9) Nonblack Compounding Ingredients, R. F. Wolf. (10) Butadiene-Styrene Rubbers, J. D. D'Ianni. (11) Nitrile and Polyacrylate Rubbers, G. A. Daum. (12) Butyl Rubber, W. L. Dunkel, R. F., Neu, and R. L. Zapp. (13) Neoprene, J. P. Munn. (14) Hypalon Synthetic Rubber, F. W. Keeley. (15) Polysulfide Polymers (Thiokol), J. S. Jorczak. (16) Silicone Rubbers, J. C. Montermoso. (17) Reclaimed Rubber, J. M. Ball. (18) Latex, Sponge, and Foam, G. G. Winspear and R. R. Waterman. (19) Physical Testing, A. E. Juve. (20) Processing Equipment, D. C. Chase. *Index.*

MATHEMATICS

Nonlinear Problems in Random Theory. Norbert Wiener. Cambridge, Mass., Technology Press of Massachusetts Institute of Technology; New York, John Wiley & Sons, Inc., 1958. 131 pp., diagrs. $4.50.

In an effort to make selected timely and important research studies more readily accessible to libraries and independent workers, the Massachusetts Institute of Technology has launched a series of "Technology Press Research Monographs" of which Professor Wiener's contribution is the first. The present monograph contains a number of lectures given to advanced students at M.I.T. in which the author examines the role of nonlinear processes in physics, mathematics, electrical engineering, physfology, and communications theory. The two final lectures are devoted to problems in the statistical mechanics of gases; the results, though tentative, provide a new approach to research in gas and plasma theory.



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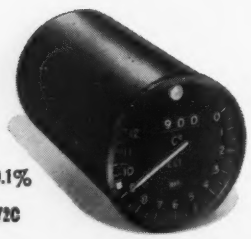

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The Theory of Matrices. F. R. Gantmacher. 2 Vols. New York, Chelsea Publishing Co., 1959. Vol. 1, 374 pp. Vol. 2, 276 pp. $6.00 each.

The present work is an English translation, by K. A. Hirsch, of the Russian-language book *Teorsia Matrits* which is based on lecture courses given during the last 17 years by Professor Gantmacher at the Universities of Moscow and Tiflis and at the Moscow Institute of Physical Technology. The two volumes are complete and unabridged, and the only changes in content are those made by the author himself late in 1958 and early in 1959. The bibliography, containing over 350 items, has also been brought up to date and, wherever possible, references to the Russian literature have been replaced by references to the corresponding English literature. Also, the notation has been brought into conformity with Western usage—e.g., the notation for the zero elements of various systems.

The book is designed not only for mathematicians but for specialists in closely allied fields; consequently, Professor Gantmacher has so shaped his presentation as to demand of the reader only the mathematical knowledge that would be gained in a normal program of higher technical education.

A Treatise on Differential Equations. George Boole. 5th Ed. New York, Chelsea Publishing Co., 1959. 735 pp. $6.00.

This fifth edition consists of the fourth edition with the "supplementary volume" appended and paged consecutively with it. The first edition appeared in 1859; the second in 1865, under the editorship of I. Todhunter.

MILITARY AVIATION, ORDNANCE

German Secret Weapons of the Second World War. Rudolf Lusar. Transl. from the German by R. P. Heller and M. Schindler. New York, Philosophical Library, Inc., 1959. 264 pp., illus., diagrs. $10.

PACKAGING

Package Design Engineering. Kenneth Brown. New York, John Wiley & Sons, Inc., 1959. 263 pp., illus., diagrs., tables. $8.50.

The material presented in this book was originally prepared for a course in industrial package design given by the author at the University of California at Los Angeles. The first eight chapters cover the basic fundamentals in static and dynamic mechanics, strength of materials, and stress analysis that are required by the packaging engineer to provide him with the necessary background for solving structural and dynamic packaging problems. Four chapters are devoted to the design characteristics of the tension spring, rubber shear mount, solid cushioning, and canvas strap suspension systems. Four additional chapters discuss the peculiarities of corrugated, sheathed crate, plywood, and metal shipping containers, and there are three chapters illustrating the engineering fundamentals and design application of dehumidification and pressurization, vibration, and package test instrumentation.

Mr. Brown is a member of the Technical Staff, Space Technology Laboratories, Inc., and of the Technical Teaching Staff, U.C.L.A.

PHYSICS

Quantitative Molecular Spectroscopy and Gas Emissivities. S. S. Penner. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1959. 587 pp., diagrs., tables, folding charts. $15.

The theoretical and experimental studies considered in this text are representative of the type of research problem encountered in connection with the development of modern propulsion devices. Most of the fundamental topics treated are mentioned only briefly in standard reference works on spectroscopy, and it is the hope of the author that the present work will serve for students in applied science as an introduction to the literature on a class of radiation problems that fall, to a large extent, into the temperature range intermediate between that of interest to the molecular spectroscopist on the one hand, and the astrophysicist on the other.

Although several important chapters require some knowledge of spectroscopy and quantum mechanics for proper comprehension, the chapters on infrared emissivities, on optical techniques for the measurement of flame temperatures, and on the effect of radiation on the burning of solid and liquid propellants should be intelligible with little or no previous preparation. Throughout the book the emphasis is on atomic and molecular problems, not on radiative transfer calculations, which are treated exhaustively in both the astrophysical and the engineering literature.

The author is associated with the California Institute of Technology.

RESEARCH

Symposium on Basic Research. Dael Wolfle, Editor. Sponsored by National Academy of Sciences, American Assn. for the Advancement of Science, and the Alfred P. Sloan Foundation, and Presented at Caspary Auditorium of the Rockefeller Institute, May 14–16, 1959, N.Y. (AAAS Publn. No. 56.) Washington, AAAS, 1959. 308 pp., illus., diagrs. $3.00.

(*Continued on page 116*)

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to specialists in the aero/space industry. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

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940. Administrative Engineer—A young man with 6 years in the aircraft industry with three major firms. Experience includes administration, weights engineering, and reliability. Working toward Master of Business Administration degree. Specialized in systems and procedures. Desires location in Long Island or New York City. Presently employed but readily available.

939. Aeronautical Engineer—Graduate of University of Michigan in February, 1952. Propulsion speciality. Four and a half years with West Coast airframe company in engineering test laboratory (fuel and engines). Over 3 years with Midwest engine manufacturer as a specialist in altitude and environmental testing. Some supervisory experience. Licensed Professional Engineer (Mechanical) in State of Ohio. Age 36. Desires a change for better chance of advancement.

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Books (Continued from page 114)

Contents: The Need for New Knowledge, J. R. Oppenheimer. Basic Research in the United States, A. T. Waterman. The Paradox of Choice, W. O. Baker. Basic Research and the Liberal Arts College, I.. M. Gould. Basic Research and the State University, C. A. Elvehjem. Basic Research and the Private University, L. A. DuBridge. Capsule Conclusions, J. R. Killian, Jr. Basic Research: A Technological Savings Account, C. H. Greenewalt. Science: Handmaiden of Freedom, D. D. Eisenhower. Basic Research in Government Laboratories, A. V. Astin. Basic Research in Industrial Laboratories, J. B. Fisk. Basic Research in Private Research Institutes, M. A. Tuve. Support of Basic Research from Government, P. E. Klopsteg. Support of Basic Research by Industry, R. E. Wilson. Support of Basic Research from Private Philanthropy, R. S. Morison. The Support of Basic Research: Summary of the Symposium, D. Wolffe. *List of Participants.*

ROCKETS

Sounding Rockets. Homer E. Newell, Jr. New York, McGraw-Hill Book Co., Inc., 1959. 334 pp., illus., diagrs., tables. $12.50.

In this study of the principal rockets used for geophysical and solar research, Dr. Newell reviews the development and scientific application of sounding rockets in the United States, England, France, and Japan from the end of World War II to the start of the International Geophysical Year on July 1, 1957. The U.S.S.R. is not mentioned. The author, who is presently Assistant Director for Space Sciences, NASA, also furnishes the reader with a means of evaluating the relative merits and disadvantages and the relative suitabilities of various rockets.

Contents: (1) The High-Altitude Sounding Rocket, H. E. Newell, Jr. (2) The Use of Rockets for Geophysical and Solar Research, H. E. Newell, Jr. (3) The Use of Sounding Rockets for Military Research, R. C. Truax. (4) The Aerobee Rocket, J. A. Van Allen, J. W. Townsend, Jr., and E. C. Pressly. (5) The Aerobee-Hi Rocket, J. W. Townsend, Jr., E. C. Pressly, R. M. Slavin, and L. Kraff, Jr. (6) Deacon and Cajun, W. J. O'Sullivan, Jr. (7) ASP, R. B. Cox. (8) Loki-WASP, J. E. Masterson. (9) Balloon-Launched Rockets for High-Altitude Research, J. A. Van Allen. (10) Aircraft-Launched Rockets, Part I by M. D. Ross, Part II by L. Kraff, Jr., and R. M. Slavin. (11) Nike-Cajun and Nike-Deacon, L. M. Jones, W. H. Hansen, and F. F. Fischbach. (12) Terrapin, S. F. Singer and A. L. Lawrence. (13) Viking, H. E. Newell, Jr. (14) British Sounding Rocket—Skylark, J. F. Hazell and B. B. Dorling. (15) French Sounding Rockets—Véronique and Monica, E. Vassy. (16) Japanese Sounding Rockets—Kappa and Sigma, H. Itokawa. (17) Future Sounding Rockets, H. E. Newell, Jr., E. C. Pressly, and J. W. Townsend, Jr. (18) Facilities for the Firing of Sounding Rockets, H. E. Newell, Jr. (19) Artificial Satellites of the Earth, H. E. Newell, Jr. *Index.*

THERMODYNAMICS

Chemical Process Principles; Part 2, Thermodynamics. Olaf A. Hougen, Kenneth M. Watson, and Roland A. Ragatz. 2nd Ed. New York, John Wiley & Sons, Inc., 1959. 605 pp., diagrs., tables. $9.75.

The present edition brings together in one volume the theoretical development and practical applications of the basic engineering science of thermodynamics, plus advanced treatment of the more specialized developments of chemical engineering thermodynamics. The great advances made in the development of chemical engineering curricula in terms of the basic engineering sciences since the appearance of the first edition in 1947 have resulted in a text containing at least 70 per cent of new material. The treatment of thermodynamics in the fields of fluid flow and power generation has been enlarged, and principles of fluid flow with consideration of thrust have been extended to the supersonic range, as well as to the flow of compressible fluids through ducts and nozzles. The thermodynamic problems of a wide range of internal-combustion engines are analyzed in terms of basic scientific principles; problems of mechanical design are not treated.

Drs. Hougen and Ragatz are Professors of Chemical Engineering, University of Wisconsin; Dr. Watson holds the same title at the Illinois Institute of Technology.